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A MODEL OF SCHEDULING IN A TWO-PORT SHIPPING SYSTEM

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A MODEL OF SCHEDULING IN A TWO-PORT SHIPPING SYSTEM

by

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ABSTRACT

A closed, dynamic, mathematical model is used to study scheduling in a two-port system.

The model will predict on a daily basis: the amount of cargo waiting at each port for shipment; the status of each dock -- empty or occupied and if occupied, by which ship; the destination, estimated-time-of-arrival, amount of cargo on board, number of days in port and at sea, and the daily speed for each individual ship.

Upon completion of a test case, the model will predict, by ship: the total time at sea and the cost thereof; the total time spent in port including time lost waiting for a vacant dock; the overall voyage cost and the average-daily-cost of each ship. Additionally, the model will predict the total amount of cargo generated for shipment at each port and the maximum quantity it builds up to at any time. The model will predict the cost of warehouse space needed to store freight awaiting shipment by the system.

The model will accept any combination of ship sizes and speeds desired. If required, the model will alter automatically a ship's established ETA to insure that upon arrival at its destination a vacant dock with cargo waiting to be put on board will be available.

The model has the following restrictions: It is limited to two ports. It assumes sufficient stevedore gangs and equipment to permit simultaneous loading and unloading of different vessels in the same port on a 24-hour basis. There is no distinction between different cargo classes. The model does not provide for cargo delays. The model considers its ships always in service with

no time lost for maintenance. The model uses the same fuel-used vs. speed curve in calculating daily fuel consumption for all ships--regardless of their size, shape, or type of propulsion. The model uses the same average-daily-operating-cost-figure for all ships.

Numerous test cases are studied to determine

(a) the effects of vessel size and speed on scheduling;

(b) the benefits of altering a ship's speed to coincide with a vacant dock; and

(c) the advantages of sailing a partially loaded ship to provide a vacant dock for an inbound ship.

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I am indebted to the United States Navy for giving me the opportunity of furthering my formal education.

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INTRODUCTION

Background

Today as never before the well being of society depends in large measure upon the efficient operation of the nation's industries. The management of these industries must accept this responsibility and rise to the challenge. Industrial leadership can no longer afford the luxury of depending upon intuition and myths to guide vast industrial enterprises. In short, the management of these industries must become more of a science and less of an art.

One of the principal reasons that management in industry is not more scientific is that man has never been able to study complex, economic systems as a unified whole; he has been forced to deal with them piecemeal; and consequently, man has never mastered the underlying principles that control their operation.

Now, for the first time, two concepts offer some hope in the study of these economic systems. Both were outgrowths of Operations Research--a new scientific discipline used in the study of the decision-making process.

Definition of a Model

The first concept is that of a model; a model can be many things. Usually a layman thinks of a model (if he thinks of one at all) as a three-dimensional replica of an object. But to a scientist or engineer the word, model, is synonymous with representation. The Pythagorean theorem is a model, a chemical formula is

a model and for that matter, so is a musical score. Therefore, a model can be abstract and describe something in symbols and mathematical equations as well as being a physical replica. Additionally, models can be static or dynamic--a static model describes relationships that do not vary with time while the interactions of the dynamic model's variables can change with time.[1*]

Hereafter, this thesis will be concerned with dynamic, mathematical models of economic systems and they will be called industrial dynamic models. The term industrial dynamic model was first used by Dr. Jay W. Forrester in his book, Industrial Dynamics.[2]

Industrial Dynamic Models

Industrial dynamic models resemble the structure and/or behavioral characteristics of a real-life counterpart, and they can be manipulated in any way without affecting their counterparts. This permits their use in determining the effects of policy changes on the real-life system they represent. Moreover, they can be used to evaluate information as to its accuracy, worth and timeliness; and operating experience can be obtained from the model in a fraction of the time and cost it takes to generate experience with the real system.[3]

But, it should be stressed that these models cannot now be used to make predictions of specific events in the real-life system at particular times in the future.[4] This is true because many variables simply cannot be accounted for: for instance, human behavior plays an important part in every industry; but so far, it has been impossible to reduce it to a series of meaningful equations. External disturbances constantly change and are difficult to account

*Footnotes listed at the end of Chapter VI.

; examples might be--a natural disaster, stock market slump, or labor strike to name a few. So, when dealing with complex economic models, the best that can be hoped for is that they behave like their real-life counterparts.

Industrial dynamic models focus attention upon themselves and their real-life counterparts. This is perhaps one of the most valuable contributions of constructing a model; just building one enforces precision in thinking.[5] A model challenges every concept of the real-life system, for each one must be reviewed and analyzed to incorporate it into a model; assumptions about the real-life system, which have been made unconsciously, are brought to the surface and must be accounted for.

The second of the two important concepts mentioned earlier is the use of dynamic, mathematical models in conjunction with the modern, electronic, digital computer to simulate behavior. This means to create, artificially, history that is similar to the actual performance of the system in real-life. Artificially creating performance history with a complex mathematical model involves numerous iterative calculations; the high speed computer can perform these calculations rapidly and efficiently, thereby making simulation feasible.

Purpose of the Thesis

The goal of this study is to investigate the construction of a useful model of a shipping organization.

The shipping industry was chosen because the author is familiar with it and because the industry is in serious trouble and can benefit from a new approach to its problems.

Simulation models as such are not new in shipping; for example, Matson Navigation Company reports that they have a very sophistocated simulation model of a freighter fleet. Matson's model required six man-years of programming time before it became operational.[6]

It is felt that if a useful model could be built in a reasonable time and consequently lower cost, management's interest in model simulation would be renewed. For in this area lies management's best hope of improvement.

The model constructed in this work is described in Chapter III.

Chapter II

PURPOSE OF THE MODEL

Before any useful model can be constructed, its purpose must be clearly defined. The purpose of this model is to serve as a testing device for evaluating policy decisions affecting scheduling in a two-port shipping system. Its objective is to reveal policies that materially influence the system--producing better or worse system performance.

Better performance will be defined as the compromise that produces the better balance between the cost of allowing cargo to build up in port and the expense of operating enough ships to totally eliminate cargo build-up. It makes no sense to have an overabundance of shipping capacity to prevent cargo build-up if ships lie idle waiting for a vacant dock or to have cargo unloaded or loaded--operating costs would certainly be excessive. It is just as foolish to provide too little capacity and accumulate a large backlog of cargo; shippers would lose confidence in the company's ability to deliver their goods on time and would turn to a competitor. So, it is essential to maintain the best balance between the two; this is what is meant by effective scheduling.

Effective scheduling depends upon many factors such as the distance between ports, weather conditions at sea, the type of cargo, port regulations (working hours, etc.), and the size (cargo capacity) and speed of the vessels in use.[7]

The value of the model as a testing device lies in its ability to reveal how and to what degree each of these factors affects the system.

For example, the effects of size and speed on scheduling can be evaluated by carrying out a series of controlled experiments on the model. This is done by testing different fleets* of ships and holding all other factors--weather conditions at sea, port regulations, type of cargo--constant.

Studying the behavior of the model as it reacts to the different experiments may provide valuable insight into the nature of the effects of size and speed on the system performance. This insight may lead to more effective individual ship designs. The supertanker of 60,000 to 100,000 tons is a classic example of designing more effective ships. Just a few years ago this size vessel was considered uneconomical.[8] Today supertankers are the mainstay of the world tanker fleet. But the point is that industry had to be forced by the Suez Crisis of 1956 into building what later proved to be an enormously profitable ship.[9] Had the industry known more about the effects of size and speed, it might have built supertankers of its own volition--Suez or no Suez.

Size and speed are vital considerations when a company must determine which is better for its operations--a few, large, fast ships or many, small, slow ones. It may well be that a combination of varying sizes and speeds produces the most efficient system operation. And still another related problem is: should a company deliberately alter a vessel's speed to synchronize its ETA with an empty dock and cargo waiting to be put on board.

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*A fleet can be composed of ships having similar characteristics--size and speed--or they may differ, ship by ship, in size and/or speed.

These are just a few of the problems dependent upon the effects of size and speed on system performance; similar questions would [illegible] if the other factors were tested.

It is exceedingly difficult to establish policies covering problems of this nature using conventional analysis, i.e., trying to formulate theories about system operation by observing the system in real life. The shipping system is too complex; it has too many interacting variables. Of course, conducting experiments on a real-life system would help; but the tremendous investment in capital equipment (ships, cargo handling gear, terminal facilities) discourages experimentation where the results cannot be foretold.

As pointed out in Chapter I, the only practical alternative at the present time is to create a simulation model and experiment with it. The costs are insignificant; the benefits may be inestimable. If the model which is the subject of this study can be used in this manner, it will have served its purpose.

Chapter III

DESCRIPTION OF THE MODEL

Classification

The model is essentially a description of a two-port shipping system. It tells how conditions at one point in time lead to subsequent conditions at a later point in time. To do this the model is closed, dynamic, mathematical and stable.

The adjective closed is used because once initial conditions have been input to the model, it has sufficient internal intelligence to operate indefinitely without receiving additional inputs from an external source.[10]

It is a mathematical model because mathematic equations are used to describe the real system instead of a physical device. And it is dynamic in that it deals with time-varying interactions.

So far the description of the model fits Dr. Forrester's definition of an Industrial Dynamics Model with one important exception. As presently configured, the model does not take into account the concept of information-feedback. Dr. Forrester states that:

> An information-feedback system exists whenever the environment leads to a decision that results in action which affects the environment and thereby influences future decisions.[11]

This concept can be built into the model; it is regretted that time did not permit its inclusion.

Similarity To A Real System

This model is not an exact duplicate of the system it represents. It is more of a caricature than a duplicate, i.e., it is a crude "likeness" rather than an "exact" replica of a closed, two-port, shipping system.

The model will not predict actual conditions in the real system at some time in the future, but it does exhibit the same behavioral characteristics as the system it simulates. The model reacts the same way a real shipping system does to excess shipping capacity--ships lie idle. If we restrict the number of docks in the model it reacts just as the real system would with fewer docks--ports become congested. A speed-up of cargo handling rates in the model reduces port turn-around time just as would happen in real life.

Even though the model is not exactly like a real, closed, two-port system, it must contain the essential elements of one if it is to accomplish its intended purpose.

Major Elements

One such element is cargo; the primary purpose of any shipping system is to move cargo from one point to another. The model must provide this freight for shipment at each port and it must provide it in a realistic manner. Under certain conditions the cargo input at a port can be a constant daily value; under others, the cargo input will be a random daily value; and under still others, the cargo input depends upon seasonal fluctuations in freight.[12] All of these situations occur in real life and the model is equipped to handle each one. But in doing so it contains two important assumptions about cargo. The first is that there is an in-balance in the cargo input at each port; i.e., there is more cargo available for shipment at one port than the other. And the second is that there is no distinction between different classes (bulk, general, liquid) of cargo. It would be simple enough to eliminate both of these

assumptions; however, time did not permit this.

Ships form another important element of the model just as they do in a real-life system. For ship operation consumes the major portion of the revenues of a shipping company.[1] The company must provide its ships with crews and pay their wages. The company must establish and maintain schedules; it must repair its ships and provide for routine maintenance; and it must purchase insurance, provisions, and fuel for all ships.

The foregoing gives some idea of the enormous number of variables associated with operating ships. Any attempt to faithfully account for all of them would make the model so complex as to obscure the more important aspects of ship operation.

Therefore, the ship operation portion of the model contains simplifying assumptions. The model assumes, for instance, that individual ships differ only in their speed and the amount of cargo they can carry. This permits the model to use the same fuel-used vs. speed curve in calculating fuel consumption for all ships--regardless of their size or shape. And another example of the assumptions made to simplify the model is that it considers its ships always in service with no time lost for maintenance.

These assumptions permit the model to concentrate on the fundamentals of ship operation. One such fundamental is that the model must control ship movements at all times. For example, it may land a vessel only during certain hours of the day, being careful that the vessel moves only into a vacant dock. Inbound cargo must be off-loaded and outbound cargo loaded on board. A new destination must be established and the vessel's ETA to that destination computed.

Once at sea the model may alter a vessel's speed but not its direction. If the model is to control ship movement, all of the above must be co-ordinated and executed on time.

Another major element of the model is the ports or, more specifically, port one and port two. The significance of terminal (port) operations is apparent when it is realized that the loading and unloading of cargo is the single most expensive phase of ship management. Cargo-handling-costs average from 40 to 60 per cent of total costs.[14] In addition a company must provide warehouse storage space for shippers' cargo; it is customary to grant a shipper or consignee five, seven, or ten days' free storage on cargo.[15]

Again, the model must contain simplifying assumptions to prevent being smothered by the complexities of real life. One is that all cargo is handled (loaded and unloaded) at the same rate. And another is that each port has sufficient stevedore gangs to permit simultaneous loading and unloading of different vessels on a 24-hour basis.

The fourth and final element of the model is accounting. Every organization must account for its revenues and record its expenses using standard accounting practices. However, to gain simplicity the accounting element of the model must deviate from this. The model only records expenses associated with ship operation and warehousing of cargo. Moreover, the myriad expenses of operating a ship are lumped into two average, daily costs. One is the average, daily, in-port cost and the other is the fuel expense determined by the speed the vessel is traveling--it is essentially a daily operating cost at sea. The expense of warehousing cargo is the average daily cost of storage space in the port of San Fran-

cisco.[16]

Warehousing cost could include a computed penalty cost for allowing cargo to build up in port. The effect of lost sales through customer dissatisfaction could be accounted for in this manner. Unfortunately time did not permit the inclusion of this concept in the model.

As pointed out, each of the four elements of the model (cargo, ship, port, and accounting) contain many variables significant to the behavior of the model. These variables must interact according to certain precisely-defined rules if the model is to achieve simulation. Several examples are: no ship may [illegible] its maximum speed or carry more cargo than its maximum capacity; and no ship may dock after the closing hours of the port. A ship must remain at port one for a full load but it may sail from port two if there is no cargo for shipment. These rules are unchangeable.

Initial Conditions

In addition to the rules mentioned above, the variables are affected by initial conditions which are set at the beginning of a simulation run. They cannot be altered by a source external to the model until the run is completed. These conditions are critical as different tests on the model are performed by changing some of them.

The more important ones are: the speed, cargo carrying capacity, amount of cargo actually on board, destination, and estimated-time-of-arrival of each individual ship used by the model; the total number of ships in use; the cargo input, cargo handling rates, and working hours for both ports; and the option that the model will

use. The model options will be explained in greater detail later.

Sequence of Operation

Inputting initial conditions starts a model simulation run. Master time--the number of days the model has been in operation--is one for the first cycle. A cycle is defined as one complete pass through the model for both ports.

The first cycle begins with the generation of cargo for both ports. To do this the cargo generator depends upon a constant, daily, increment of cargo as an input; this increment can be derived from past operations of the company (historical) or it can be based upon cargo forecasts (computed). The cargo generator can supply for each port a constant, daily increment or a random daily increment or a cyclical increment or even a randomized, cyclical increment depending upon the initial conditions. The cargo generator adds the daily, generated increment to the cargo already at the port to obtain the total amount of cargo awaiting shipment.

This amount is compared with the available warehouse space at both ports. If the cargo exceeds the storage space, the amount of additional warehousing needed is computed and the cost is added to the total warehousing cost. The model assumes that the additional space is always available--an assumption that is not necessarily true in real life.

At this point the model concerns itself solely with port one. It determines if any vessel in port one is scheduled to leave. If so, the model establishes port two as the destination. It figures the ship's ETA to port two using its maximum cruising speed (kts.--nautical miles per hour).

The model then establishes the daily fuel consumed for all ships at port one or at sea heading for port one. The model uses the curve in figure one to compute fuel consumption for all ships.[17]

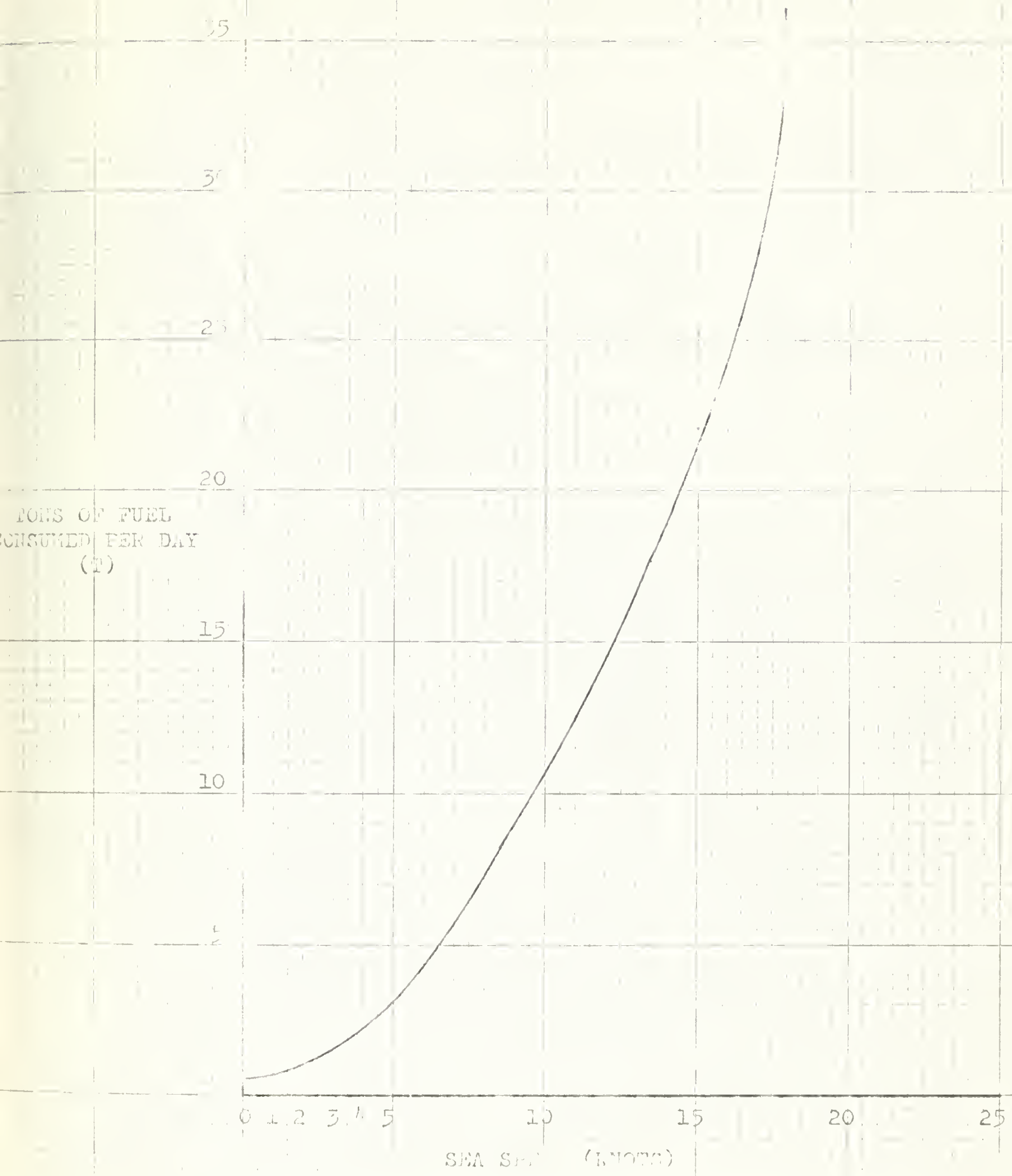
It should be noted that fuel consumption depends upon the speeds the vessels are making at the beginning of the day. If a ship lands at or departs from a port later in the day, the actual consumption will be over or under stated for that day. This is considered a minor error of the model that will tend to cancel itself out over a period of time.

The model will now land ships whose ETAs equal master time and whose destination is port one--provided there is a vacant dock available. Once a ship has been docked the model will discharge its cargo and reload it. Loading and unloading proceeds at a constant rate. (See Fig. 2)[18] When a ship is loaded, its time-of-departure is computed.

After all ships, scheduled to sail from port one at master time equal to one, have been sailed; after the fuel consumption has been computed for all ships at or headed to port one; after all ships due to arrive at port one have arrived; and after all ships at port one have been loaded or unloaded as the case may be, then the model will switch to port two. And the entire process will be repeated step by step.

Once the model has finished looking at both ports, master time is compared with final time; if it is less, master time in incremented by one and the model, keying first on port one and then on port two, passes through the process again.

This sequence is repeated again and again. Master time is incremented by one day after each cycle until, finally, master time



$$T = .5 + 2.08\left(\frac{S}{6}\right) + 1.25\left(\frac{S}{6}\right)^2 + .666\left(\frac{S}{6}\right)^3$$

Fig. 1

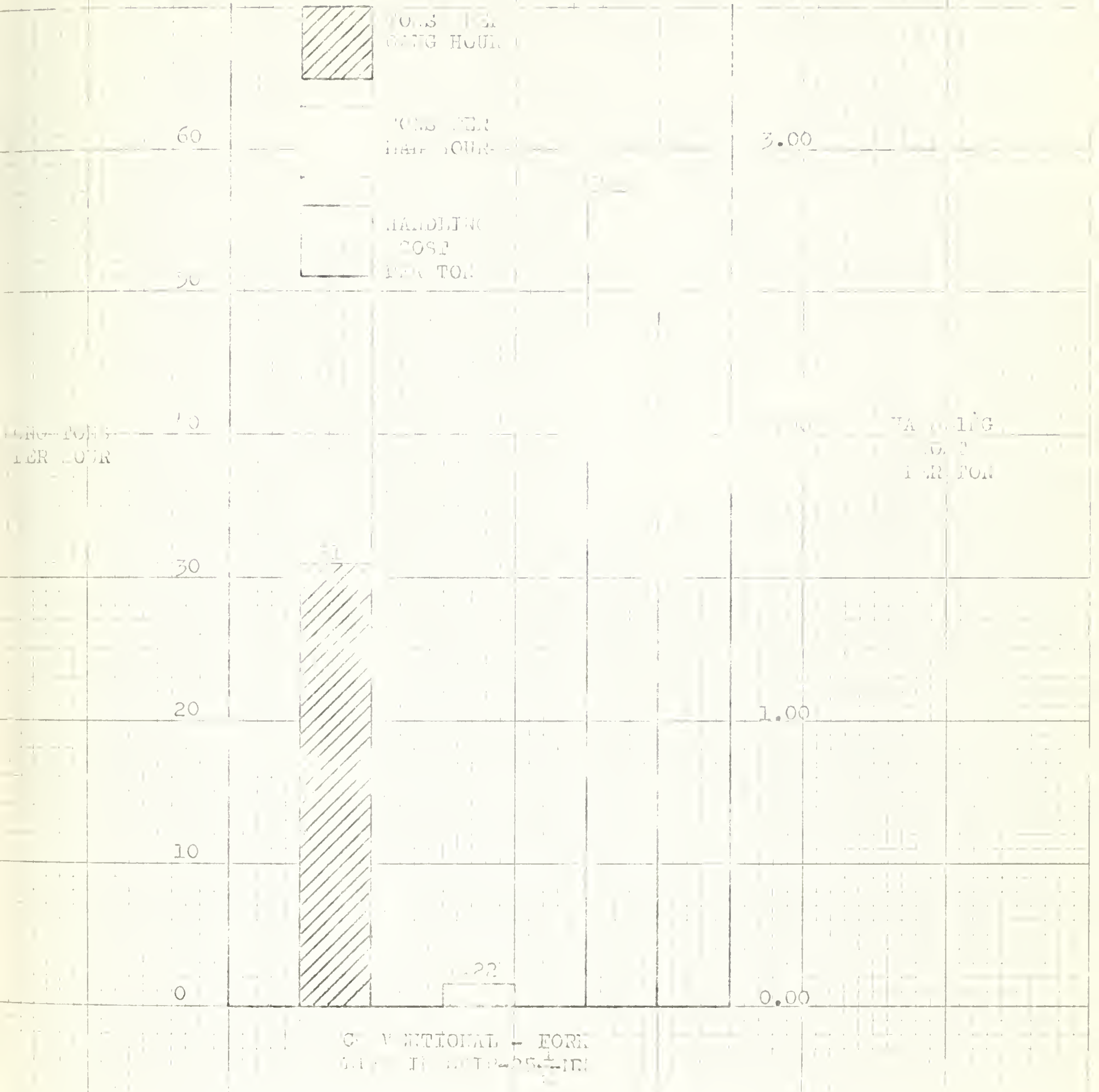


Fig. 2

equals final time and the answers are printed out.

The model contains two options not found in a real system. If desired, the model will adjust a ship's ETA (provided the ship is headed for port one) to coincide with an open dock and cargo awaiting shipment. The model does this by looking ahead and simulating the amount of cargo that will be available at port one on the day the ship is scheduled to land. If there will be no cargo or if all the docks are occupied, the model figures the earliest moment cargo will be available or a dock will open up. The model establishes this earliest moment as the new ETA of the ship and adjusts the ship's speed accordingly. In this manner a vessel's speed may be decreased to zero or increased to its maximum cruising speed. The model will do this each day a ship is at sea headed for port one.

The second option is that if an inbound ship is scheduled to land at port two but all the docks are occupied, the model will search for a ship at port two that is loading. If it finds one, the model will sail it even though it does not have a full load. This permits the inbound ship to land as scheduled.

To sum up, the model is closed, dynamic, and mathematical. Its behavior resembles that of a real, closed, two-port system even though it contains numerous simplifying assumptions. Its purpose is to test policy decisions affecting scheduling. It does this by tracing through time histories for many different sets of conditions.

Chapter IV

DESCRIPTION OF COMPUTER PROGRAM

The translation of the model into a computer program resulted in a MAINLINE program that controls supporting subprograms in which the majority of the calculations are performed. The purpose and principal equations of the subprograms will be explained first. The way they fit into the MAINLINE will be described when the operation of the MAINLINE is explained.

The first of the important subroutines is CATL (cargo generator). Its purpose is to provide cargo at each port for shipment by the system. CATL accomplishes its purpose with the following two equations:

(4.1)

```
CPD(NP) = CPDC(NP)*(CR1(NP)+CR2(NP)*RR(A))*(1.+SINCO(NP)*SIN(T*AA))
```

The symbols represent variables as follows:

CPDC	Cargo Per Day Constant in "thousands" of tons per day.
NP	Number of the Port. (Dimensionless)
CR1	The constant that determines the degree of randomness.
CR2	CR2(J) = 2.*(1.-CR1(J)) (When CR1 = 1. CR2 = 0.
RR	Random number. (Dimensionless)
SINCO	Amplitude of annual fluctuation.
T	Master time. (Days)
AA	Constant equal to 2.*3.1415927/360. (Dimensionless)

(4.2)

```
CW(NP) = CW(NP)+CPD(NP)*DELT
```

The symbols represent variables as follows:

CW Cargo for shipment in "thousands of tons"

UNIT One day

Both (4.1) and (4.2) are defined as equations; however only (4.1) is an equation in a mathematical sense where (4.2) is a Fortran statement. Hereafter the word equation will apply to Fortran statements as well as mathematical equations. The symbols used in equations (4.1) and (4.2) will be in Fortran language to aid in identifying them in the computer programs.

By the proper choice of values for CR1 and SINCO the cargo generator can output for each port a variety of cargo increments. For example, when CR1 equals 1. and SINCO equals 0. the cargo generator will output a constant daily increment. If CR1 equals 1. and SINCO is greater than zero, the output will be a cyclical increment. But if CR1 equals 0. and SINCO equals 0., the output will be a randomized increment varying from zero to twice the size of the daily increment. When CR1 equals zero and SINCO is greater than zero the output will be a randomized cyclical increment.

The cargo generator is restricted in that equations (4.1) and (4.2) do not distinguish between different classes of cargo.

The second important subroutine is DEPART. DEPART's purpose is to sail ships when they are scheduled to leave port. It computes their destination and ETA and vacates the dock they were in. The most significant calculation is in figuring the new ETA of a vessel. This is done by:

(4.3)

ETA(K) = DCK[illegible],J[illegible](I[illegible],[illegible])/ [illegible](K)*24.)

ETA Estimated-Time-of-Arrival of the K[illegible] ship. (days)

DCKTME	Time of departure of the ship from dock.	(days)
DIS	Distance between ports.	(miles)
SPEED	Maximum cruising speed of the ship.	(nautical miles per hour)
24.	Constant	(hours per day)

SCAN is another important subroutine whose purpose is to synchronize a vessel's ETA with an open dock and cargo waiting to be put on board. If it is used, SCAN only alters the arrival time of ships heading to the port with the greatest, daily, cargo input--this is port one in the model.

The principle equations of SCAN are:

SMLTCW = SMLTCW+CPDC(NP)*(1.+SINCO(NP)*SIN(THETA)) (4.4)

SMLTCW	Simulated cargo.	(thousands of tons)
CPDC	Cargo Per Day Constant.	(thousands of tons per day)

Equation (4.4) computes the anticipated cargo that will be available on the day the ship is scheduled to arrive.

UNLOAD = CARGO(K)/ALDTME(NP) (4.5)

OADTME = HOLD(K)/ALDTME(NP) (4.6)

TADT = -(SMLTCW+CPDC(NP)*(UNLOAD*OADTME)-HOLD(K))/CPDC(NP) (4.7)

CARGO	The cargo that is on board the Kth ship.
ALDTME	Unloading/loading rate of the NPth port.
UNLOAD	Unloading time in days.
HOLD	Maximum cargo the Kth ship can carry.
OADTME	Loading time in days.

TADD The time in days to be added to or subtracted from a vessel's ETA.

Equation (4.[illegible]), (4.[illegible]), and ([illegible].7) compute the number of days by which a ship's ETA must be altered to insure that there is cargo to be loaded when the ship arrives.

ETAMIN = ((OSPD*(ETA(K)-T))/MAXVSPD(K))+T (4.8)

OSPD The speed at which the model is traveling. (nautical miles per hour)

MAXVSPD(K) Maximum cruising speed of the Kth ship. (nautical miles per hour)

Equation (4.8) computes the earliest ETA of the Kth ship from its present position, using the maximum speed of the ship.

The purpose of the FUEL Subroutine is to compute the amount of fuel a vessel consumes. Equation (4.9) expresses the relationship between the fuel used and the speed at which the ship is traveling. (See Fig. 1)

TONS(K) = .5+2.08*(SPEED(K)/6.)+1.25*(SPEED(K)/6.)**2+.666*(SPEED(K)/6.)**3 (4.9)

TONS The tons of fuel consumed at the speed the ship is traveling.

The purpose of ARRIVE, which is another significant subroutine, is to bring a ship into port. The purpose of LOAD--another important subprogram--is to load and discharge cargo from ships and to compute their time-of-departure. The equations used by ARRIVE and LOAD are simple and obvious; therefore, they will not be listed here.

<u>Sequence Of Operation In The Mainline Program</u>

The sequence of operation in the MAINLINE program is identical to the model; however, it will be explained in greater detail. This will provide a more complete picture of how the program simulates performance history.

The first calculation of the MAINLINE, after the initial conditions have been read in, is the incrementation of master time by delta time (one day). The MAINLINE calls MATL which returns the amount of cargo available for shipment at port one and port two. These figures are obtained from equations (4.1) and (4.2).

Using the amount of cargo awaiting shipment at each port, the MAINLINE computes the required warehouse space and the cost of the space. At this point the MAINLINE calls DEPART using port one as the principal argument; i.e., DEPART ignores port two.

Using time-of-departure (dock time), DEPART searches each dock in port one. If a dock time falls between master time and master time plus one (indicating a vessel is due to leave), the number of the vessel occupying the dock is obtained. A new destination is determined for this ship--in this case port two; its estimated-time-of-arrival for that destination is computed using equation (4.3); and the time it spent in port is added to the total time it has been in all ports. Then, the ship is sailed by setting its dock time to zero. This is done to indicate that the dock is now empty. Of course, if there are no ships in port or if none are scheduled to leave during this time period, the computer immediately returns to the MAINLINE program.

The MAINLINE now calls FUEL using port one as the principal

argument.

If a vessel is heading for port one, FUEL computes the tons of fuel that the vessel consumes per day at the speed it is traveling; this is added to the total fuel the vessel has consumed since the beginning of the problem. The FUEL subprogram is restricted in that it uses the same fuel-used vs. speed curve (see Fig. 1) in calculating daily fuel consumption for all ships--regardless of their size, shape, or type of propulsion. As pointed out in Chapter III FUEL computes fuel consumed based upon the speed a ship is making at the beginning of the day. Of course, this will be in error if a ship lands or departs later in the day as its speed will not be constant all day. However, this error will tend to cancel itself out in time.

After FUEL is completed, the MAINLINE passes on to the ARRIVE routine where every ship is searched. If one is found heading for port one (the port the computer is keying on) and whose ETA occurs between master time and master time plus the closing time of the port, ARRIVE prepares to dock the ship. It does this by searching all docks to find a vacant one; if there are none, ARRIVE calculates the earliest moment one will be available. If a dock opens up before the closing time of the port, the ETA of the waiting ship will be changed to coincide with the opening of the dock and the ship will land. On the other hand, if a dock does not become vacant, the ETA of the waiting vessel will be increased by one day and it will go into a dock delay status.

After ARRIVE has searched all ships, the MAINLINE calls LOAD again using port one as the controlling argument.

LOAD searches all docks in port one. If they are all empty, LOAD is terminated; but if a ship is in dock, LOAD determines its status--loading or discharging cargo. A ship loading cargo has a zero value for its ETA while a vessel discharging cargo has a negative ETA. The zero for a loading ship and negative ETA for an unloading merely allows the computer to make the distinction.

The loading and unloading of cargo proceeds at a maximum rate (see Fig. 2) because the program assumes sufficient stevedore gangs and cargo handling equipment to permit simultaneous loading and unloading of different vessels in the same port on a 24-hour basis. Another contributing factor is that there is no distinction between different cargo classes--all cargo is handled at the same rate.

When a vessel completes the loading operation, its time-of-departure (docktime) is computed and retained for DEPART. For port one, loading is terminated when the ship has a full load; however, for port two loading is completed the moment there is no more cargo to be put on board. So, a vessel in port two may sail partly empty.

Now, the principal argument becomes port two; and the computer must pass again through the DEPART, FUEL, ARRIVE, and LOAD subprograms.

At this point a cycle is completed; master time is compared with final time: if it is less, it is incremented by delta time and a new cycle is begun. This process of looking first at port one and then at port two is repeated again and again until master time equals final time (the time set for the termination of the program). This concludes the description of the MAINLINE and supporting programs in their most basic form without any options.

If it has been elected to use the SCAN subroutine option and if port one is the principal argument, [illegible]

after completing DEPART. The purpose of SCAN is to alter the ETAs of vessels headed for port one to insure a vacant dock on arrival with cargo waiting to be put on board.

SCAN does this by searching each vessel until it finds one whose destination is port one and whose ETA is greater than master time. SCAN then computes by using equation (4.4) the amount of cargo that will be available when the vessel is due to land at port one. If a ship is already in port or if a ship is due to arrive before the one in question, the amount of cargo it can hold is subtracted from the simulated cargo.

Using equation (4.7) the number of days to be added to or subtracted from the established ETA is computed. Equation (4.8) computes the earliest time that the ship can get in, sailing at its maximum speed. The minimum ETA is compared with ETA plus the additional time. If the ETA plus additional time occurs sooner than the minimum ETA, then minimum ETA becomes the established ETA. If the ETA plus additional time is greater than the minimum ETA, then it becomes the established ETA.

Now that the cargo situation has been satisfied, SCAN must insure that a dock will be open. So, the earliest time that a dock will be available is computed and compared with the newly established ETA. If the established ETA occurs before a dock will be available, the earliest moment a dock is free becomes the established ETA.

Based upon the final value of ETA, the speed of the vessel is computed and using this as an input, the MAINLINE calls FUEL, HANDLE, and LOAD. The pattern of operation is identical to the one followed when SCAN is not used.

Upon completion of the required number of cycles the computer calls the ACCOUNT subroutine to figure cost and the answers are printed out.

The second option concerning sailing a partially loaded ship from port two to create a dock vacancy for an inbound ship, is handled in the ARRIVE subroutine. It is straight forward and contributes a few extra statements to the basic subroutine. The additional statements are obvious and will not be discussed.

This concludes the descriptions of the computer programs. Chapter V will discuss the various tests performed using the computer programs.

Chapter V

TESTS ON THE MODEL

General Concepts

It will be recalled that the purpose of the model is to serve as a testing device for evaluating policies affecting scheduling in a two-port shipping system. As stated previously, scheduling depends upon many factors--the type and quantity of cargo; the number, size and speed of the ships in use; port regulations; etc. Because of limited time the effects of all of these factors could not be determined.

The tests that were conducted were designed to provide answers to three questions:

(1) What are the effects of size and speed on scheduling, i.e., system performance?

(2) Should a vessel's speed at sea be altered to take advantage of a vacant dock and cargo waiting to be put on board?

(3) Is is worth-while to sail a partially loaded ship to permit an inbound ship to land as scheduled?

Make-up Of The Tests

Every effort was made to provide the model with realistic test data. The sizes and speeds chosen for the model's ships in each test corresponded to realistic ships operating under United States Registry. For example, when the model used a ship of 9,000 tons and maximum speed of nine Kts., a counterpart existed in real life--the C1-[illegible] freighter. Model ships of 9,000 tons and 15 Kts. correspond to a real-life C-3 freighter. And a model ship of 1[illegible],000 tons and [illegible] Kts. is identical to the C-4 freighter.[19] The normal [illegible] hours of [illegible] port of San Francisco. In making up tests of different fleets

of ships, one major difficulty is in providing the same system, cargo, carrying capacity. In other words, a fleet composed of four 12 Kts. ships of 12,000 tons each cannot be expected to handle as much cargo as [illegible] 5 Kts. ships of 15,000 tons. Clearly, these two fleets of ships are not equivalent. So, any conclusion that one type of fleet is inherently superior to the other would be invalid.

The problem of using equivalent yet differing fleets of ships was of major concern throughout the development of the model. In fact, it is very difficult to make up equivalent fleets of ships using realistic--as to size and speed--vessels. The fleet combinations finally decided upon are not exactly equivalent in cargo capacity; however, numerous tests revealed that they are approximately equal.

<u>What The Tests Revealed About The Model</u>

Initial tests proved that the model as originally conceived was not flexible. It performed its operations instantaneously. That is, when a ship docked, the model would compute immediately its departure time. This meant that the model was in effect loading and unloading the ship instantaneously. The model would then ignore that ship until its departure time (some days or cycles later). This severely limited the expansion of the model to include new functions in the shipping process.

The model was re-designed to execute its operations over a simulated time span of minutes, hours, or days as occurs in real life. Take the case of a vessel landing. Only that amount of cargo that can be removed in a 24-hour period is taken off the ship. The next model cycle--24 simulated hours later--another day's cargo is loaded or unloaded as the case may be [illegible] until the

ship is full at which time it is sailed. This not only makes the model more flexible but makes it much easier to think through different situations as they happen in a logical time sequence.

The tests also revealed that de-bugging the model is an extremely tedious process primarily because there are no "right" answers to compare with the model test results. All that is available is the results of other tests on the same model. Late in the development of the model and after numerous test cases had been run, the model was thought to be free from error. The answers seemed reasonable and plausible. However, merely altering the starting position of the various ships (instead of starting ship one from port one, starting it from port two) disclosed that the model was extremely sensitive. The answers were markedly different from previous cases using identical fleets but different starting positions. An error was located in the SC[illegible] subroutine; it was corrected; and the test cases rerun. Again the model proved inordinately sensitive to the initial starting positions of the test fleet. A simple, logical error was eventually located in the least likely part of the program--the READ routine. Therefore, it can be said that de-bugging is essentially a time-consuming, trial-and-error process.

Results

Table A lists the results of seventeen test cases on the model.

The column headed SPEED refers to the speed of the ships. If only CS (constant speed) is listed, it means that all ships have a maximum speed of 12 knots. If on the other hand the notation VS: 9, 11, 13, 15 is given, it means that the ships have different maximum speeds and they are 9, 11, 13, 15 knots respectively.

Column II entitled [illegible] refers to the maximum cargo-carrying capacity of the ships. CH means all vessels have the same capacity and it is 10,000 tons. VH means that the ships have varying cargo capacities.

A YES in Column III, SCAN, means that the model used the option of deliberately altering ships' speeds to coincide with an open dock and cargo waiting to be put on board at the destination of the ship. NO means this option was not used.

A YES in Column IV, OPT 2, signifies that the option to sail a partially loaded ship to permit an inbound ship to land has been used.

The figure listed under Column IV, CMAX1, refers to the maximum cargo that built-up in port one at any time during the simulation run. For example, 7.82 in Column IV would mean that 7,820 tons was the maximum value of cargo build-up in port one.

Column VI, [illegible] COST, indicates the cost of operating the particular type fleet for an entire simulation run.

Now that Table A has been described, the results will be discussed. Comparing cases 1 with 2, 4 with 5, 7 with 8, and 10 with 11 in Column VI clearly shows that using SCAN reduces the system operating costs. The reason SCAN is cheaper in all cases is that it allows the ships to travel at less than their maximum speeds thereby reducing fuel consumption at sea. SCAN also reduces the time spent in port by providing vacant docks and cargo to be loaded on board.

In comparing case 2 (the option to leave port 2 to make room for an incoming ship) with case 3 (without the option) it can be seen that there is no difference in the system operating costs.

Conclusions

The results indicate that sufficient tests have not been conducted on the model to justify any conclusions concerning the effects of size and speed on scheduling. So question one will remain unanswered.

The results do indicate the value of altering a ship's speed; therefore, the answer to question two is yes.

Table A indicates that it makes no difference if a partially loaded ship is sailed to permit an inbound ship to land as scheduled. [illegible]; the author feels that additional testing is needed to completely justify this conclusion. The answer to question three is a tentative yes.

The overriding conclusion that can be drawn from the results is that additional testing is absolutely necessary. For example, the cases of random cargo input and random cyclical cargo input were never tested and should be carried out before any additional modifications or revisions are made to the model.

TABLE A

NUMBER OF SHIPS: 4

NUMBER OF SIMULATED DAYS: 1000

CARGO INPUT: Constant 1.63 thousands of tons per day.

	I	II	III	IV	V	VI
[illegible]	SPEED	HOLD	SC.	[illegible]	[illegible]	[illegible] COST
1	CS	CH	[illegible]	[illegible]	7.82	3,17[illegible],870.84
2	CS	CH	NO		7.82	3,194,070.56
3	CS	CH		YES	7.[illegible]	[illegible]
4	[illegible]:9,11,13,14.8	VH:9,11,13,14.8	[illegible]	[illegible]	15.8[illegible]	2,[illegible]01,1[illegible]3.[illegible]
5	"	"	NO	[illegible]O	17.50	[illegible],195,[illegible]
6	[illegible]:9.5,11,13,[illegible]	CH	YES	YES	22.[illegible]	2,841,231.4[illegible]
[illegible]	[illegible]S:10,11,13,15	CH	YES	YES	24.30	[illegible],812,026.[illegible]
8	"	"	NO	[illegible]	[illegible].75	3,742,9[illegible].1[illegible]
9	"	VH:9,11,13,15	YES	YES	63.[illegible]	3,091,0[illegible]
10	VS:9,11,13,14.9	VH:9,11,13,14.9	YES	[illegible]	15.39	2,884,419.00
11	"	"	[illegible]	[illegible]	[illegible]	[illegible],124,686.09
12	VS:9,11,13,1[illegible]	[illegible]:9,11,13,14.8	Y[illegible]	[illegible]	[illegible].0[illegible]	2,894,570.62
[illegible]	V[illegible]:9.5,11,13,15	CH	YES	YES	[illegible].69	2,829,091.56
14	VS:10,11,13,15	CH	[illegible]	YES	24.0[illegible]	[illegible],802,660.59
15	CS	VH:9,11,13,15	YES	YES	52.08	3,033,879.12

Chapter VI

CONCLUSIONS

General

The purpose of this study was to investigate the construction of a useful model of a shipping system. A model was built that did answer conclusively one of the scheduling questions put to it and did provide a tentative answer to another. For this reason it is concluded that the model is useful.

Another conclusion of a general nature is that the problems associated with building a model of a shipping system are not complicated in the sense that they require sophisticated mathematical techniques to solve. They can be thought through in a logical step by step process if given enough time.

Recommendations For Future Model Development

Another area besides scheduling of vital concern to a ship operator is adapting a vessel to its cargo.[20] Every ship operator is interested in having his ships filled with cargo that brings in the maximum revenue for its volume.

The model in its present form could be used to study this problem with a few simple modifications. The model would have to retain the amount of cargo moved by each ship. Also, the MATL subroutine would have to distinguish between different cargo commodity classes. A computed freight rate could then be applied to the tons of cargo moved. This would permit the COST routine to compute the revenue derived from each ship.

The problem of when to dry-dock a ship could be studied by introducing a mechanical breakdown generator into the model. The effects

of bad weather on speed at sea could be studied with a Storm generator.

And finally the model could become a true Industrial Dynamics Model if the concept of information-feedback was introduced.

All of these modifications could be made without altering the basic structure of the existing model. [illegible] to increase the number of ports would require a major revision.

By now the author hopes that it has been made clear that models of the type discussed in this thesis [illegible] can be considered complete. That is, that they can answer any question put to them concerning a shipping system. This is not so. Rather, the model can be developed to different levels of sophistocation to handle different types of questions.

To sum up, the construction of a simulation model is a long, arduous task; however, the author feels that the benefits far outweigh the difficulties. Not only can the model test alternative solutions to a given problem which could not be obtained in any other manner; but it provides the user with a better, more fundamental understanding of the real-life system it simulates. This alone is a worthwhile benefit of building and using a model.

REFERENCES

1. Jay W. Forrester, *Industrial Dynamics*, (Cambridge, Massachusetts: The M.I.T. Press, 1961), p. 30.

2. *Ibid.*

3. *Ibid.*, p. 56.

4. *Ibid.*, p. 56.

5. *Ibid.*, p. 57.

6. Foster L. Weldon, "Operational Simulation of a Freighter Fleet," *Research Techniques In Maritime Transportation*, Pub. 720 (1959), p. 23.

7. Carl E. McDowell and Helen M. Gibbs, *Ocean Transportation*, (New York: McGraw Hill Book Company, Inc., 1954), p. 175.

8. Col. Lane C. Kendall, "Development of the Oil Tanker," *U.S. Naval Institute Proceedings*, (Washington, D.C., April 1957).

9. Alfred I. Raff, *Dynamics of the Tankship Industry*, S.M. Thesis, Dept. of Naval Architecture and Marine Engineering, (M.I.T. Press, 1960), p. [illegible].

10. Forrester, p. [illegible]1.

11. Forrester, p. 14.

12. Weldon, p. 23.

13. McDowell and Gibbs, p. 156.

14. McDowell and Gibbs, p. 1[illegible]1.

15. McDowell and Gibbs, p. 172.

16. U.S. Government, Census of [illegible], Vol. 15, pp. [illegible].

17. "Economic [illegible] of Cargo [illegible]," [illegible], [illegible], 1952, pp. 86-87.

18. F. S. Macomber, "Cargo Handling Studies [illegible] Containerization," Research Techniques In [illegible] Transportation, Pub. 720, (1959), p. 96.

19. U.S. Government, "Organization, Technical and Logistical Data," Dept. Of Army Field Manual, (FM101-10 Part 1, October, 1961), p. 557.

20. McDowell and Gibbs, pg. 114.

BIBLIOGRAPHY

General

1. Committee of American Steamship Lines, "Progress of the U.S. liner fleet under the Merchant Marine Act, 1936," Washington, December, 1964.
2. Denholm, J.F., "The problem of time in shipping economics" (extracts from a paper), Fairplay, March 4, 1965.
3. Farmer, Richard N., "Efficiency in United States flag ocean transportation," Bloomington, Indiana, The author (1964).
4. Ferguson, Allen R., "The economic value of the United States merchant marine," Northwestern University Transportation Center, Evanston, Illinois, 1961.
5. Thorburn, Thomas, "Supply and demand of water transport; studies in cost and revenue structure of ships, ports and transport buyers with respect to their effects of supply and demand of water transport of goods," Stockholm School of Economics Business Research Institute, 1960.
6. Sturmey, S.G., "British shipping and world Competition." London: Athlone Press, 1962.
7. National Research Council, "Maritime transportation of utilized cargo; comparative economic analysis of break-bulk and unit load systems," Maritime Cargo Transportation Conference, Washington, 1959.
8. Farrar, Donald E., "Some factors that affect the overhaul cost of ships: An exercise in statistical cost analysis," Naval Research Logistics Quarterly, December, 1963.

9. Hoffman, L.D., "Efficient and economical practices will reduce the cost of American ships," January 15, 1962.

Computer Applications in Ship Scheduling and Routing

10. Batchelor, James, "Operations research; an annotated bibliography," Saint Louis: St. Louis Academy Press, 1959-1964.

11. Beckman, Martin, "Studies in the economics of transportation," New Haven, Conn.: Yale Univ. Press, 1956.

12. Fielder, R., "Route estimating by computer; use of digital computing techniques," Shipping World, December 27, 1961.

13. Bartlett, T. E., "Determining the Minimum Number of Transport Units Required to Maintain a Fixed Schedule," Operations Research, Volume 5, No. 1, February, 1957, p. 135.

14. Beckmann, Martin J., Charles B. McGuire, and Christopher Winston, "Studies in the Economics of Transportation," Yale University Press, 1956.

15. Bellman, Richard E., "Notes on the Theory of Dynamic Programming VII - Transportation in Models," The Rand Corporation, November 28, 1955, p. 771.

16. Charnes, Abraham and M. H. Miller, "A Model for Optimal Programming of Railway Freight Train Movements," Management Science, Volume 3, No. 1, October, 1956, pp. 74-93.

17. Ferguson, Allen R. "Applications of Linear Programming to Aircraft Routine Problems," The Rand Corporation, April 29, 1955, P. 668A.

18. Ferguson, Allen R. and George B. Dantzig, "The Allocation of Aircraft to Routes - An Example of Linear Programming Under Uncertain Demand," RM-1833, December 7, 1956, Management Science, Volume 3, No. 1, October, 1956, pp.45-73.

19. Ford, Lester, and D. R. Fulkerson, "Construction of Maximal Dynamic Flows in Networks," The Rand Corporation, 1077, May 7, 1957.

20. Germane, Gaytin E., Joseph C. Corey and William E. Rogers, "A New Concept of Transportation Movement." California: Stanford University, March 19[illegible].

21. Koopmans, Tjalling C., "Optimum Utilization of the Transportation System," Econometrica, Supplement to the July 1949 issue, Volume 17, No. 5, 384.

APPENDIX A

TITLE: MAINLINE

DESCRIPTION: This program performs the necessary steps in a freighter fleet simulation model.

LANGUAGE: FORTRAN IV (IBM 7040 COMPUTER)

VARIABLE*	TYPE**	S/A***	I/O****	DESCRIPTION
NDOCKS	FX	A	I	Number of docks in port.
DCKTIM	FL	A	I;O	Time a dock will be open.
IDOCK	FX	A	I;O	Denotes a particular dock in port.
HOLD	FL	A	I;O	Amount of cargo a ship can hold.
ND	FX	A	I;O	Destination of a ship.
DIS	FL	A	I	Distance between ports.
SPEED	FL	A	I	Speed a ship can travel.
CPDC	FL	A	I	Cargo per day constant.
CR1	FL	A	I	Controls the degree of randomness.
CR2	FL	A	I	Depends upon CR1.
SINCO	FL	A	I	Introduces cyclical variation.
CW	FL	A	I	Cargo awaiting shipment in port.
ETA	FL	A	I;O	Estimated-time-of-arrival.
TCLOSE	FL	A	I	Time of closing of the port.
ENDWRK	FL	A	I	End of normal work day.
OVTIME	FL	A	I	Overtime.
WRKDAY	FL	A	I	Length of average work day.

* The variables used here have the same meaning in all subprograms.

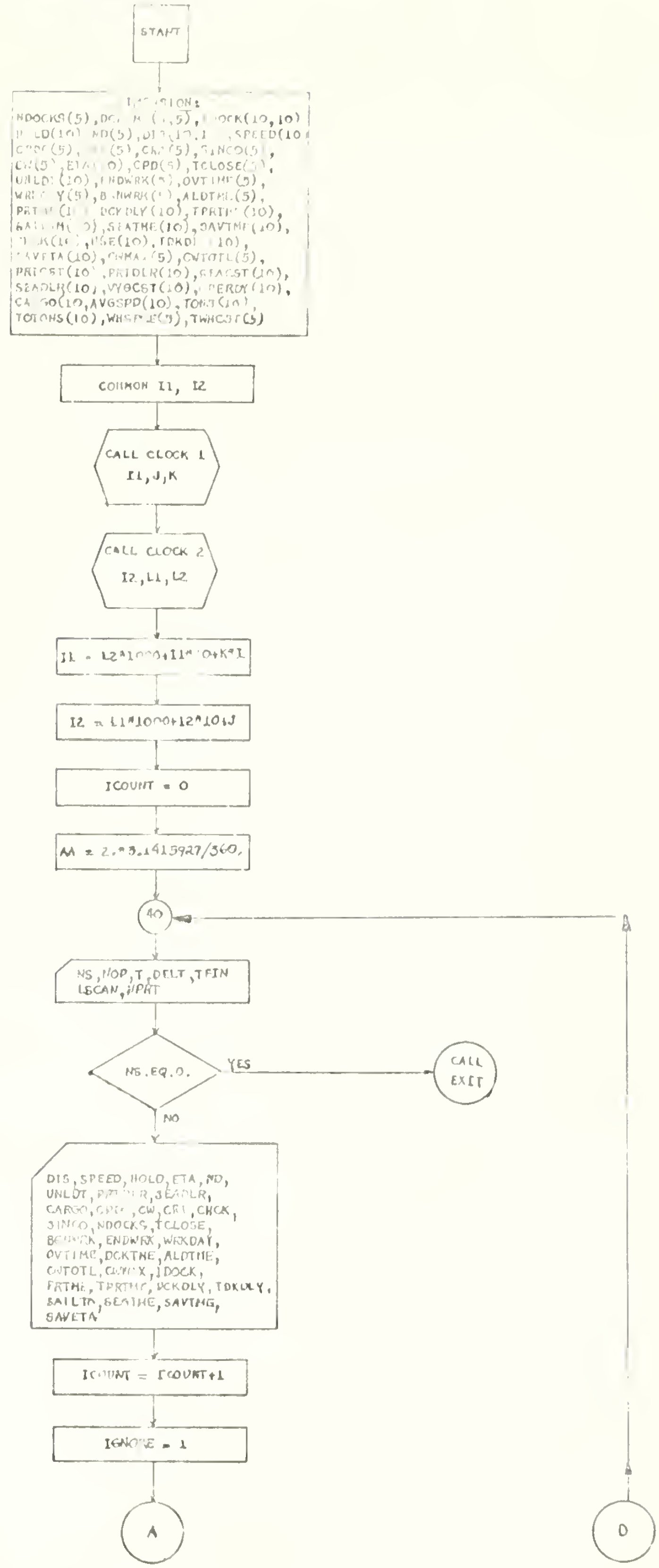
** FX - Fixed point; FL - Floating point

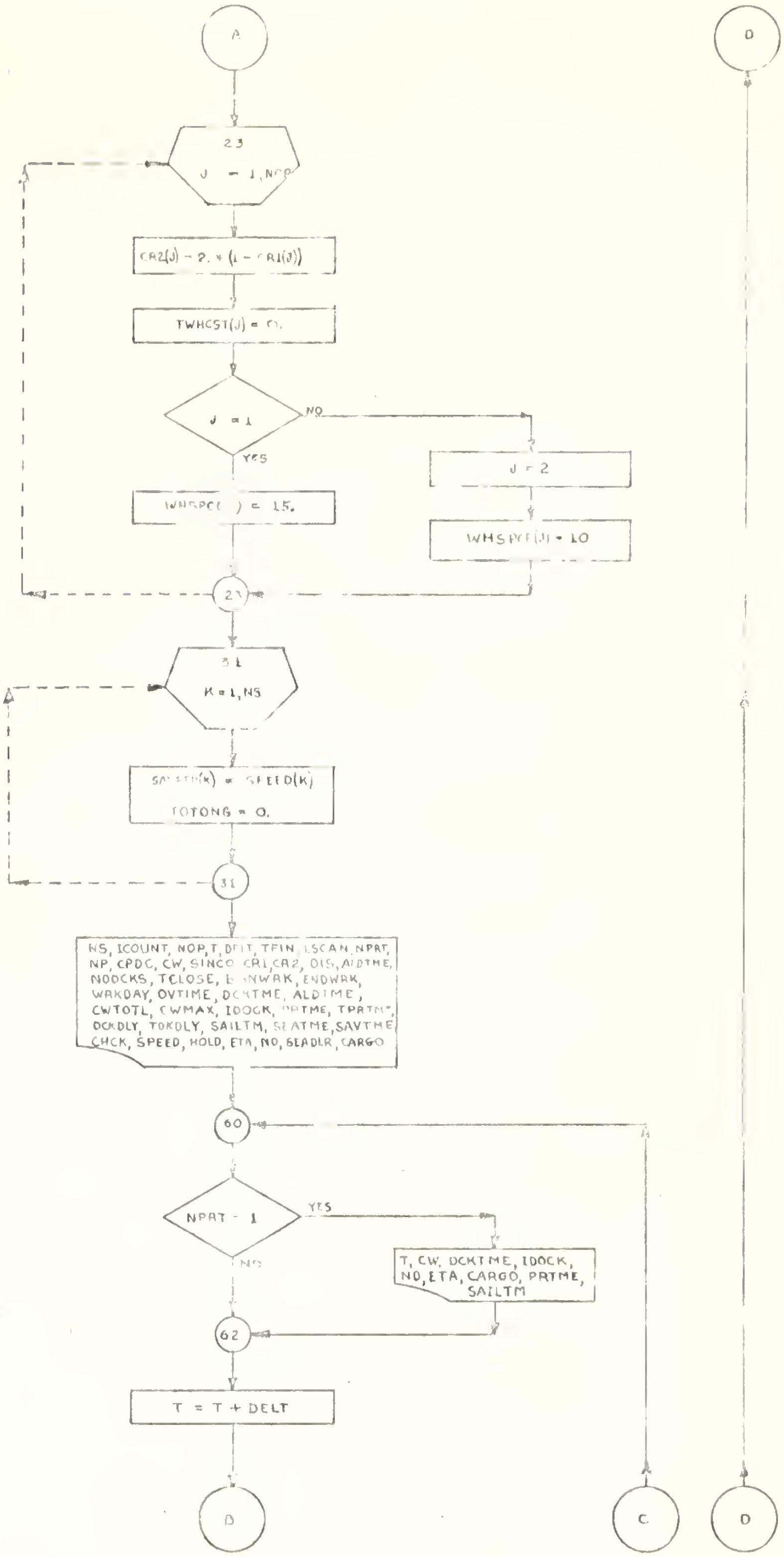
*** S - Single variable; A - Array of variables

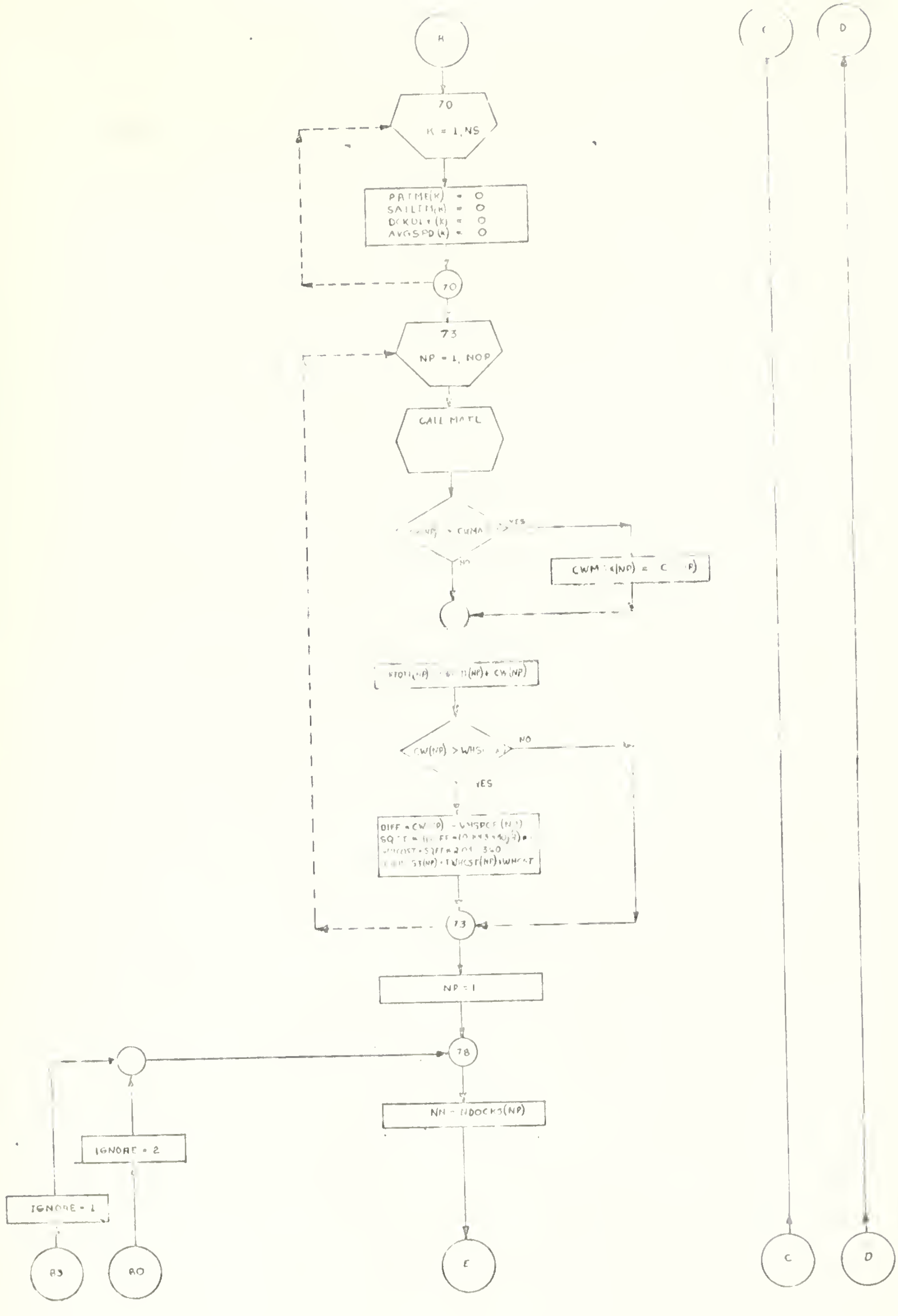
**** I - Input variable; O - Output variable

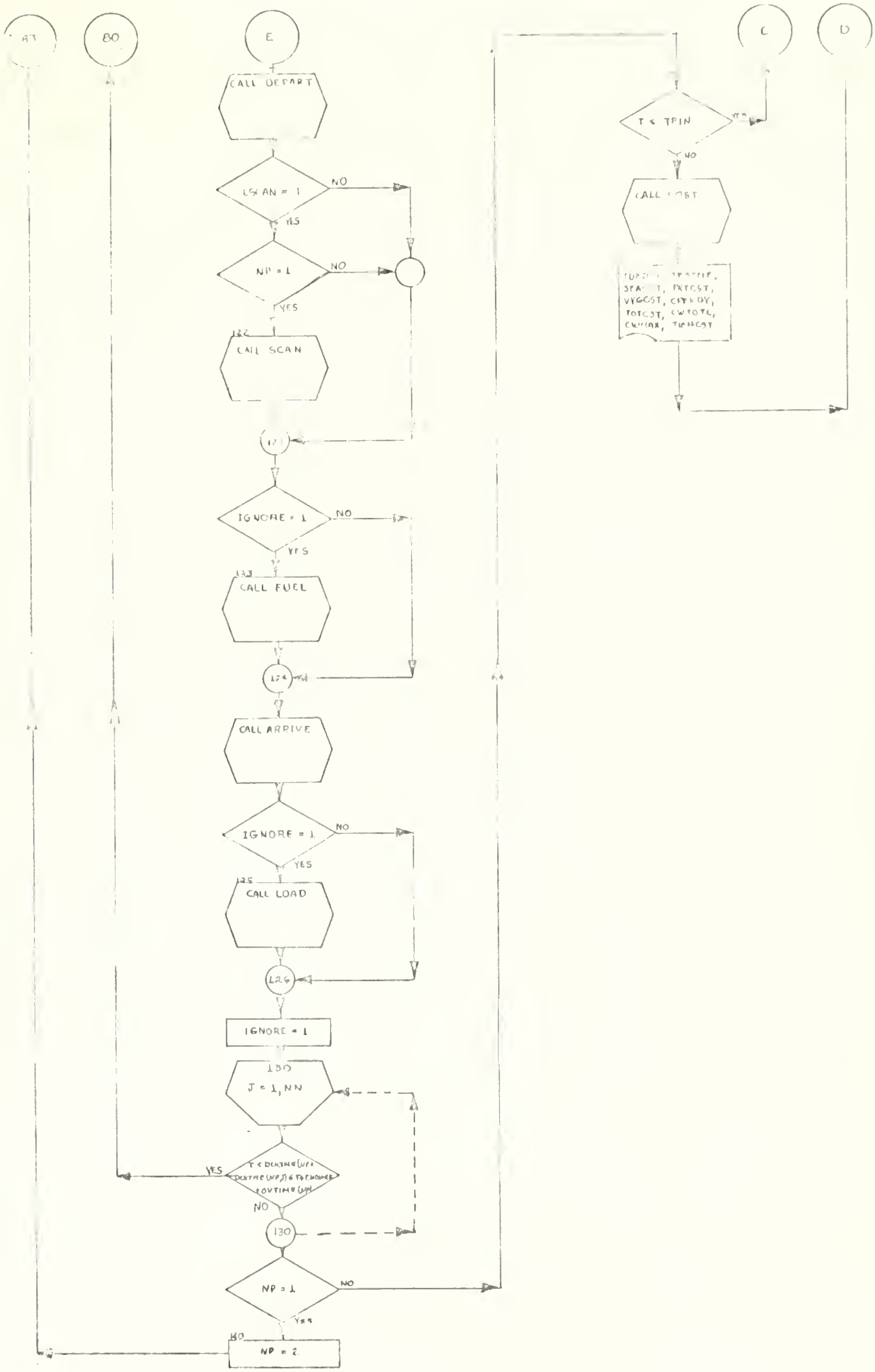
VARIABLE	TYPE	F/A	I/O	DESCRIPTION
BGNWRK	FL	A	I	Time work begins.
ALDTME	FL	A	I	Loading and unloading time.
PRTTME	FL	A	O	Time spent in port.
DCKDLY	FL	A	O	Time spent waiting for an open dock.
TPRTME	FL	A	O	Total time spent waiting for an open dock.
SAILTM	FL	A	O	Time spent sailing between ports.
SEATME	FL	A	O	Total time at sea.
TDCKDLY	FL	A	O	Total time spent waiting for an open dock.
CWMAX	FL	A	O	Maximum value cargo builds up to at any one time.
CWTOTL	FL	A	O	Maximum amount of cargo input to the port.
PRTCST	FL	A	O	Cost of staying in port.
PRTDLR	FL	A	I	Daily cost in port.
SEACST	FL	A	I	Cost at sea.
SEADLR	FL	A	I	Daily cost at sea.
VYCOST	FL	A	O	Cost for a voyage (port and sea).
OPERDY	FL	A	O	Daily operating cost.
TONS	FL	A	O	Tons of fuel consumed during a voyage.
TOTONS	FL	A	O	Total tons of fuel used in all voyages.
WHSPCE	FL	A	O	Warehouse space required.
TWHCST	FL	A	O	Total warehouse space cost.

MAINLINE PROGRAM FOR FREIGHTER FLEET SIMULATION MODEL




A
D
23
CR2(J) = 2. * (1 − CR1(J))
TWHCST(J) = 0.
J = 1
NO
YES
J = 2
WHSPCE(J) = 10
WHSPC( ) = 15.
23
31
K = 1, NS
SPEED(K)
TOTONG = O.
31
NS, ICOUNT, NOP, T, TFIN, NPRT,
NP, CPDC, CW, SINCO, CR2, DIS,
NODCKS, TCLOSE, ENDWRK,
WRKDAY, OVTIME, ALDTME,
CWTOTL, CWMAX, IDOCK,
DCKDLY, TOKDLY, SAILTM, SAVTME
CHCK, SPEED, HOLD, ETA, NO, CARGO
60
NPRT − 1
YES
NO
T, CW, DCKTME, IDOCK,
NO, ETA, CARGO, PRTME,
SAILTM
62
T = T + DELT
B
C
D


H
C
D
70
K = 1, NS
PATME(K) = 0
SAILTM(K) = 0
DCKUT(K) = 0
AVGSPD(K) = 0
70
73
NP = 1, NOP
CALL MATL
YES
NO
CWM(NP) = C(NP)
CW(NP) > WHS
NO
YES
73
NP = 1
78
NN = NDOCKS(NP)
IGNORE = 2
IGNORE = 1
83
80
E
C
D


80
E
C
D
CALL DEPART
LSCAN = 1
NO
YES
NP = 1
NO
YES
122
CALL SCAN
IGNORE = 1
NO
YES
123
CALL FUEL
124
CALL ARRIVE
IGNORE = 1
NO
YES
125
CALL LOAD
126
IGNORE = 1
130
J = 1, NN
YES
NO
130
NP = 1
NO
140
NP = 2
T < TPIN
NO
CALL COST

```
C     ------------------------------------------------------------------
C     THIS PROGRAM PERFORMS THE NECESSARY STEPS IN A FREIGHTER FLEET
C     SIMULATION MODEL
C     ------------------------------------------------------------------

    1 FORMAT (2I2, F10.1,3I2)
    2 FORMAT(1H1)
    3 FORMAT (4F10.4)
    4 FORMAT (34X,31H INPUT DATA FOR CASE NUMBER....,I2//)
    5 FORMAT (3F10.2,I2,F5.2,3F10.2)
    6 FORMAT(1X,5H NS =,I2,2X,6H NOP =,I2,2X,4H T =,F5.1,2X,7H DELT =,
     1F5.1,2X,7H TFIN =,F8.1,2X,8H LSCAN =,I2,2X,7H NPRT =,I2,2X,7H NETA
     2 =,I2)
    7 FORMAT (2(4F10.2))
    8 FORMAT (1X,6H CPDC(,I2,3H) =,F5.2,5X,4H CW(,I2,3H) =,F5.2,5X,7H SI
     1 LOC(,I2,3H) =,F5.2)
    9 FORMAT (2(I2,F10.2))
   10 FORMAT(2(1X,5H CR1(,I2,3H) =,F5.1,5X,5H CR2(,I2,3H) =,F5.1))
   11 FORMAT (2(4F10.2))
   12 FORMAT (2(1X,8H NDOCKS(,I2,3H) =,I2,5X,8H TCLOSE(,I2,3H) =,F5.2))
   13 FORMAT (6F10.2)
   14 FORMAT(2(1X,8H BGNWRK(,I2,3H) =,F5.2,5X,8H ENDWRK(,I2,3H) =,F5.2))
   15 FORMAT    (4I3)
   16 FORMAT(2(1X,8H WRKDAY(,I2,3H) =,F5.2,5X,8H OVTIME(,I2,3H) =,F5.2))
   17 FORMAT (9F5.2)
   18 FORMAT (4(5X,8H DCKTME(,I1,1H,,I1,3H) =,F5.2))
   20 FORMAT (4(5X,7H IDOCK(,I1,1H,,I1,3H) =,I2))
   21 FORMAT (1X,1H(,I1,2H),,3F8.1,6X,I2,10X, 3F10.2)
   22 FORMAT (1X,5H SHIP,1X,6H SPEED,3X,5H HOLD,5X,4H ETA,4X,3H ND,
     1H PRTDLR,3X,7H SEADLR,3X,6H CARGO)
   24 FORMAT (59X,2H (,I1,2H),,2X,I2,5F10.2)
   25 FORMAT (4F10.2)
  280 FORMAT (1X,59H TIME  CW(1)  DOCK TIME    SHIP    CW(2)  DOCK TIME
     1   SHIP)
   30 FORMAT(1H0)
   32 FORMAT (1X,F6.1,F7.2,21X,F7.2)
   33 FORMAT (14X,4H (1,I1,3H) =,F6.2,I3,11X,4H (2,I1,3H) =,F6.2,I3)
   34 FORMAT (4(5X,5H DIS(,I1,1H,,I1,3H) =,F8.1))
```

```
 FORMAT (2X,8H TPRIME(,I1,3H) =,F5.2,     DLY(,I1,3H) =,F5.2,2X
 1,8H SAVTME(,I1,3H) =,F5.  ,2X,8H SAIL(,I1,3H) =,F5.2,2X,8H ATME
 2(,I1,3H) =,F5.2,2 ,8H CHCK(,I ,3H) =,F5.2)
410FORMAT (60X,5H SHIP,1X,3H ND,  ,4H ETA,  ,6H CARGO,4X,6H PRTME,3X,
 17H    ILT  ,3X,7H  SPEED)
42 FORMAT (  X,14H CASE SOLUTION)
43 FORMAT (2X,2H (,I1,2H)  2X,7F10.2//)
  FORMAT (2(1X,8H ALDTME(,I1,3H) =,F10.2))
450FORMAT (2X,5H SHIP,4X,7H TD DLY,3  7H SEATME,3X,7H SE  ST,3X,7H TP
 1  LE,3X,7H PRTCST,3X,7H VYGCST,3X   CPE DY)
460FORMAT (10X,37H THE TOTAL COST    THIS SO    ION IS ,F10.2,1X,8H D
 1OLLARS)
47 FORMAT (1X,8H CWTOTL(,I1,3H) =,F10.2,5X,7H C MAX(,I1,3H) =,F10.2)
48 FORMAT (10X,25H WAREHOUSE COST FOR PORT(,I1,  ) IS ,F10.2)
C
C     ------------------------------------------------------------------
      DIMENSION  NDOCKS(5), DCKTME(5,5), IDOCK(10,10), HOLD(10), ND(5),
     1DIS(10,10), SPEED(10), CPDC(5), CR1(5), CR2(5), SINCD(5), CW(5),
     2ETA(10), CPD(5), TCLOSE(5), UNLDT(10), ENDWRK(5), CVTIME(5),
     3  DAY(5), BGNWRK(5), ALDTME(5), PRTME(10), DCKDLY(10),
     4TPRTME(10), SAILTM(10), SEATME(10), SAVTME(10), CHCK(10), USE(10),
     5  DLY(10), SAVETA(10), CWMAX(5), CWTOTL(5), PRTCST(10),    DLR  0
     6  SEACST(10), SEADLR(10), VYGCST(10), CPEDD (10), CARGO(10),   S
     7  D(10), SAVSPD(10), TONS(10)  TOTONS(10),   PCE(5),    CST( )
C     ------------------------------------------------------------------
      COMMON I1,I2
      CALL CLOCK1(I1,J,K)
      CALL CLOCK2(I2,L1,L2)
      I1=L2*1000+I1*10+K*1
      I2=L1*1000+I2*10+J
      ICOUNT = 0
      AA = 2. * 3.1415927 / 360.
40    READ(5,1) NS, NOP, T, DELT, TMIN, LSCAN, NPRT, NE
      IF(NS .EQ. 0) GO TO 165
      READ(5,3) ((DIS(I,J), J = 1,2), I = 1,2)
     0READ(5,5) ((SPEED(J), HOLD(J), ETA(J), ND(J), UNLDT(J), PRTDLR(J),
     1SEADLR(J), CARGO(J)), J = 1,NS)
      READ(5,7) ((CPDC(NP), CW(NP), CR1(NP), SINCD(NP)), NP = 1,NOP)
```

```
      READ(5,9) ((NDOCKS(NP), TCLOSE(NP)), NP = 1,NOP)
     0READ(5,11) ((BGNWRK(NP), ENDWRK(NP), WRKDAY(NP), OVTIME(NP)), NP =
     1 1,NOP)
      READ(5,26) ((DCKTME(NP,J), J = 1,2), NP = 1,NOP)
      READ(5,13)((ALDTME(NP), CWTOTL(NP), CWMAX(NP)), NP = 1,NOP)
      READ(5,15) ((IDOCK(NP,J),  J = 1,2), NP = 1,NOP)
     0READ(5,17) ((PRIME(K), TPRTME(K), DCKDLY(K), TDKDLY(K), SAILTM(K),
     1 SEATME(K), SAVTME(K), SAVETA(K), CHCK(K)), K = 1,NS)
      ICOUNT = ICOUNT + 1
      IGNORE = 1
      DO 23 J = 1,NOP
      CR2(J) = 2. * (1. - CR1(J))
      TWHCST(J) = 0.
      GO TO (50, 53), J
   50 WHSPCE(J) = 15.
      GO TO 23
   53 WHSPCE(J) = 10.
   23 CONTINUE
      DO 31 K = 1,NS
      SAVSPD(K) = SPEED(K)
      TOTONS(K) = 0.
   31 CONTINUE
  303 WRITE(6,2)
      WRITE(6,4) ICOUNT
      WRITE(6,6) NS, NOP, T, DELT, TFIN, LSCAN, NPRT, NETA
      WRITE(6,8) ((NP, CPDC(NP), NP, CW(NP), NP, SINCO(NP)), NP = 1,NOP)
      WRITE(6,10) ((NP, CR1(NP), NP, CR2(NP)),NP = 1,NOP)
      WRITE(6,36) (((I,J, DIS(I,J)), J = 1,NOP), I = 1,NOP)
      WRITE(6,30)
      WRITE(6,44) (( NP, ALDTME(NP)), NP = 1,NOP)
      WRITE(6,12) ((NP, NDOCKS(NP), NP, TCLOSE(NP)), NP = 1,NOP)
      WRITE(6,14) ((NP, BGNWRK(NP), NP, ENDWRK(NP)), NP = 1,NOP)
      WRITE(6,16) ((NP, WRKDAY(NP), NP, OVTIME(NP)), NP = 1,NOP)
      WRITE(6,18) (((NP, J, DCKTME(NP,J), J = 1,2)), NP = 1,NOP)
      WRITE(6,20) (((NP, J, IDOCK(NP,J), J = 1,2)), NP = 1,NOP)
     0WRITE(6,38) ((K, TPRTME(K), K, TDKDLY(K), K, SAVTME(K), K, SAILTM(
     1K), K, SEATME(K), K, CHCK(K)), K = 1,NS)
      WRITE(6,30)
```

```
      WRITE(6,22)
      WRITE(6,21) ((K, SP  (K),    (K), ETA(K),  D(K),               PRTDL
     1  (K), SEAPLR(K), CARGO(K)), K = 1,NS)
      GO TO (61,62), NPRT
   61 WRITE(6,30)
      WRITE(6,28)
      WRITE(6,32) T, CW(1), CW(2)
      WRITE(6,34) ((J, DCKTME(1,J), IDOCK(1,J), J, DCKTME(2,J),IDOCK
     1(2,J)), J = 1,2)
      WRITE(6,41)
      WRITE(6,24) ((K, ND(K), ETA(K), CARGO(K), PRTME(K), SAILTM(K),  SP
     1EED(K)), K = 1,NS)
      ------------------------------------------------------------------
      T = T + DELT
      DO 70 K = 1,NS
      PRTME(K) = 0.
      SAILTM(K) = 0.
      DCKDLY(K) = 0.
      AVSPD(K) = 0.
   70 CONTINUE
      DO 73 NP = 1,NOP
      CALL  MATL(CPDC, NP, CR1, CR2,      SINCO, T, AA, CW, DELT, CPD)
      IF(CW(NP) .GT. CWMAX(NP)) CWMAX(NP) = CW(NP)
      CWTOTL(NP) = CWTOTL(NP) + CW(NP)
      IF(CW(NP) .GT. WHSPCE(NP)) GO TO 71
      GO TO 73
   71 DIFF = CW(NP) - WHSPCE(NP)
      SCFT = ((DIFF*10.**3 * 40.) / 8.) * 1.
      WHCOST = SCFT * 2.04 / 360.
      TWHCST(NP) = TWHCST(NP) + WHCOST
   73 CONTINUE
      NP = 1
      GO TO 78
   33 IGNORE = 1
      GO TO 78
   80 IGNORE = 2
   78 N  = NDOCKS(NP)
      CALL  DEPART(NDOCKS, T, DCKTME, IDOCK, NP, HOLD, DIS, SPEED, CPDC,
```

```
     1C[illegible] [illegible], JINCO, AA, CW, DELT, ND, ETA, CPD, NN, PRTME, [illegible]KDLY,
     2[illegible], SAVTME, CHCK, SAILTM, BGNWRK, SAVETA, SAVSPD)
      GO TO (121,127), LSCAN
  [illegible] GO TO (122,127), NP
      [illegible] SCAN(NS, ND, NP, ETA, HOLD, CHCK, CH[illegible], CW, JINCO, T, AA, CAR
      GO [illegible]ME, N[illegible], SPEED, SAVSPD, IDOCK)
      GO TO ([illegible],12[illegible]), IGNORE
      [illegible] FUEL(ND, NS, NP, T, ETA, TCLOSE, SPEED, TONS, [illegible])
      [illegible]RIVE(IDOCKS, NS, NP, T, TCLOSE, UNLDT, ALDT[illegible], ETA, [illegible]
     1OV[illegible], WRKDAY, BGNWRK, IDOCK, DCKTME, ND, NN, [illegible], [illegible]KDLY,
     2T[illegible]R[illegible]E, SAVTME, SAILTM, SEATME, TDKDLY, SAVETA, [illegible], SAVSP
     3[illegible], SPE[illegible], NETA)
      GO TO (125,126), IGNORE
 1250[illegible]LL LOAD([illegible], IDOCK, ETA, CARGO, ALDTME, CW, NP, DCK[illegible], [illegible],
     1[illegible], SVTIME, HOLD, T)
 126 [illegible] = 1
      DO 130 J = 1,NN
      [illegible] .LT. DCKTME(NP,J) .AND. DCKTME(NP,J) .LE. T + [illegible](NP) [illegible]
     1 [illegible]TIME(NP)) GO TO 80
 130 CONTINUE
      [illegible] (140,150),NP
 140 [illegible] = 2
      [illegible] 83
 150 IF(T .LE. TFIN) GO TO 60
      CALL COST(NS, T, TOTCST, PRTCST, TPRTME, PRTDLR, [illegible], [illegible],
     1 [illegible]ADLR, VYGCST, CPERDY, TDKDLY, TOTONS)
      WRITE(6,30)
      WRITE(6,42)
      WRITE(6,30)
      WRITE([illegible],45)
      WRITE([illegible],43) ((K, TDKDLY(K), SEATME(K), SEACST([illegible]), TPR[illegible](K), PRTCS
     1[illegible]VYGCST(K), CPERDY(K)), K = 1,NS)
      [illegible]ITE([illegible]) TOTCST
      [illegible]IT[illegible]) ((NP, CWTOTL(NP), NP, CWMAX(NP)), [illegible]
      WRITE(6,30)
      WRITE(6,48) ((NP, TWHCST(NP)), NP = 1,NOP)
      GO TO 40
 [illegible] CALL EXIT
      END
```

```
C      INPUT DATA FOR A TYPICAL CASE.
C
C
               0.          1.      1000.  1 2 1
     0.      2500.       2500.          0.
      12.          12.          0.    1   .2    1700.00      22.40      0.
      12.          12.          6.5   1   .2    1700.00      22.40     12.0
      12.          12.          2.2   2   .2    1700.00      22.40     12.0
      12.          12.          7.1   2   .2    1700.00      22.40     12.00
       1.83        0.0          1.0         0.0         0.5         0.0         1.0         0.0
 2        .9  2           .9
       .35         .70          .35         .17         .35         .70         .35         .19
      0.00         0.0          0.0         0.0
      3.60         0.0          0.0         3.60        0.0         0.0
  1  0  0  0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
```

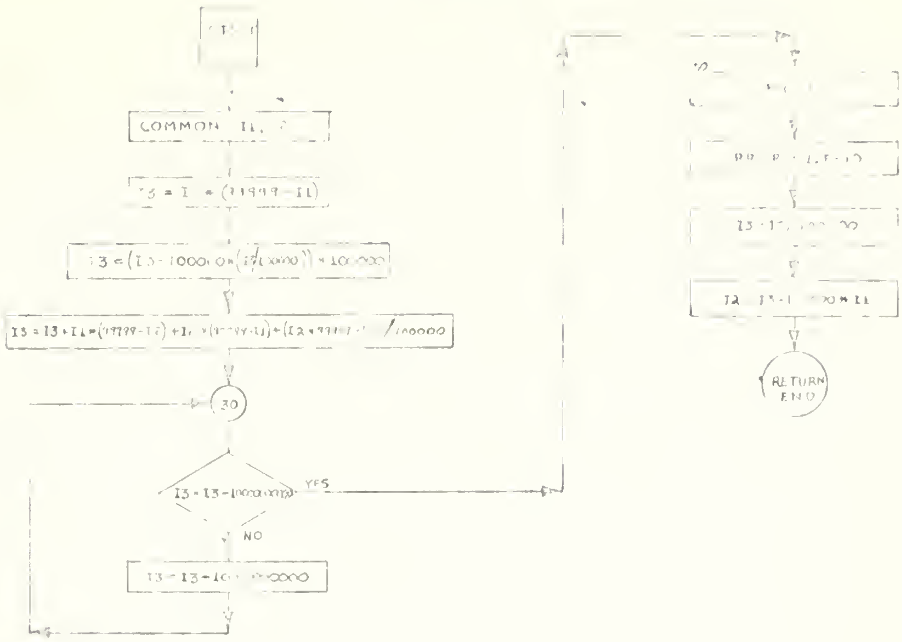
[illegible]: [illegible] - A subroutine designed to [illegible] cargo for shipment.

[illegible]: [illegible] for the values of [illegible], [illegible] complete [illegible], [illegible], [illegible] increments and [illegible] cyclic [illegible].

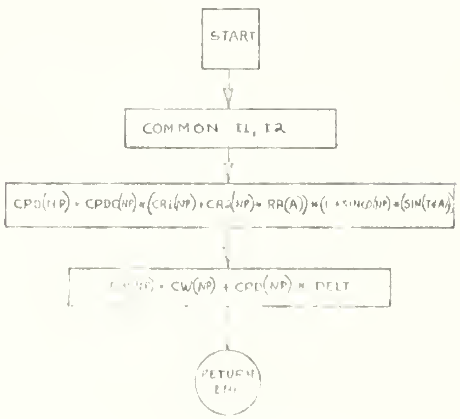
[illegible]: [illegible] (IBM 7090 [illegible])

[illegible]	[illegible]	[illegible]	I/O	[illegible]
C[illegible]	FL	A		Cargo per day.
CPDC	FL	A	I	Cargo per day constant.
C[illegible]	FL	[illegible]	O	Cargo available for shipment.
[illegible]	FL	S	I	Number of the [illegible].
C[illegible]	FL	A	I	The constant that determines the degree of randomness.
[illegible]	FL	A	I	CS[illegible](J) = 2.*(1.-[illegible](J))
[illegible]	FL	S	I	Random number.
SINCO	FL	A	I	Amplitude of annual fluctuation.
T	FL	S	I	Master time.
AA	FL	S	I	Constant equal to 2.*3.1415927/360.
DELT	FL	S	I	Delta time equal to one day.

FUNCTION RR



MATL



```
$IBFTC RR      NODECK

      ------------------------------------------------------------
      THE PURPOSE OF RR IS TO PROVIDE RANDOM NUMBERS WHEN NEEDED
      ------------------------------------------------------------

      FUNCTION RR(A)
      COMMON I1,I2
      COMMON NPLOT1,SCALEY,NAME,SCALEX,  NZERO,NDELAY,NTAG1,NTAG2,NWAIT
     1,NTAG3,NBLANK,IPLOT
      I3 = I1*(99999 - I1)
      I3 = (I3 - 100000*(I3/100000))*100000
      I3 = I3 +I1*(99999 - I2) + I2*(99999 - I1) + (I2*(99999 - I2))/100
     1000
   30 IF(I3.LE.9999999999) GO TO 50
      I3 = I3 - 10000000000
      GO TO 30
   50 RR=I3
      RR=RR*1.E-10
      I1 = I3/100000
      I2 = I3 - 100000*I1
  111 RETURN
      END
```

```
SIBFTC MATL     NODECK

      ----------------------------------------------------------------
C     MATL PROVIDES CARGO AT EACH PORT FOR SHIPMENT BY THE SYSTEM.
C     THE PROPER CHOICE OF VALUES FOR CR1 AND SINCO THE OUTPUT FOR
C     EACH PORT CAN BE A CONSTANT, DAILY, CARGO INCREMENT OR IT CAN BE
C      RANDOMIZED, DAILY INCREMENT OR IT CAN BE A RANDOMIZED, CYCLICAL
C     INCREMENT.
      ----------------------------------------------------------------
C
     0SUBROUTINE  MATL(CPDC, NP, CR1, CR2,      SINCO, T, AA, CW, DELT,
     1CPD)
      DIMENSION  CPDC(5), CR1(5), CR2(5),       SINCO(5), CW(5), CPD(5)
      COMMON I1,I2
     0CPD(NP) = CPDC(NP)*(CR1(NP)+CR2(NP)*RP(A))*(1.+SINCO(NP)*SIN(T*AA
     1))
      CW(NP) = CW(NP) + CPD(NP) * DELT
   42 RETURN
      END
```

TITLE: [illegible] - A subroutine designed to sail ships.

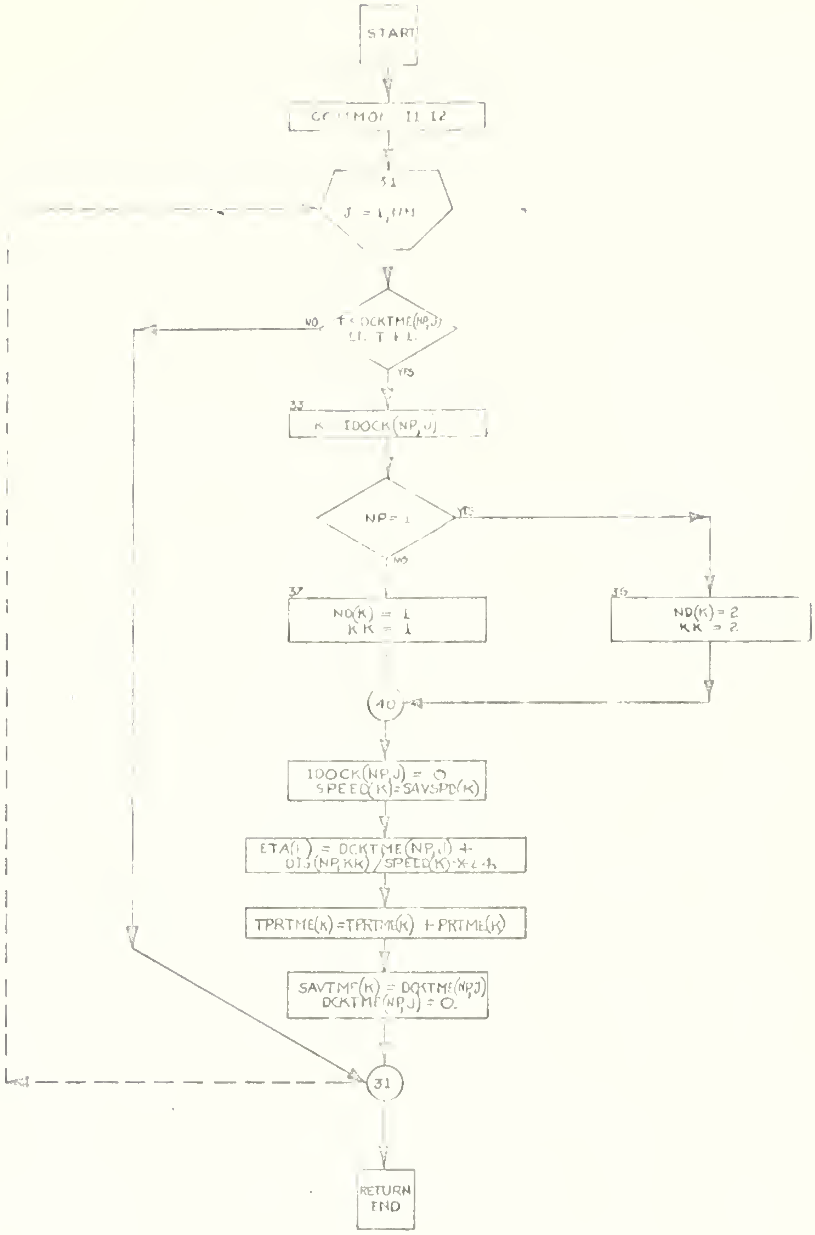
DESCRIPTION: Using a vessel's time-of-departure, [illegible] determines its destination, computes an estimated time-of-arrival, and totals the time the vessel spent in port.

LANGUAGE: FORTRAN IV ([illegible])

VARIABLE DICTIONARY:

VARIABLE	TYPE	S/A	I/O	DESCRIPTION
IN	FX	S	I	The number of docks.
T	FL	S	I	Master time.
[illegible]	[illegible]	S	I	The number of the port.
[illegible]	FL	A	I;O	Time-of-departure of shipments [illegible] to NP and J designating the port and appropriate dock.
NP	FX	S		Port that a vessel is heading for.

PART


START
COMMON I1 I2
31
J = 1, NM
NO
T < DCKTME(NP,J) .LT. T + L
YES
33
K = IDOCK(NP,J)
NP = 1
YES
NO
37
ND(K) = 1
KK = 1
35
ND(K) = 2
KK = 2
40
IDOCK(NP,J) = 0
SPEED(K)=SAVSPD(K)
ETA(I) = DCKTME(NP,J) + DIS(NP,KK)/SPEED(K)
TPRTME(K) = TPRTME(K) + PRTME(K)
SAVTME(K) = DCKTME(NP,J)
DCKTME(NP,J) = 0.
31
RETURN
END

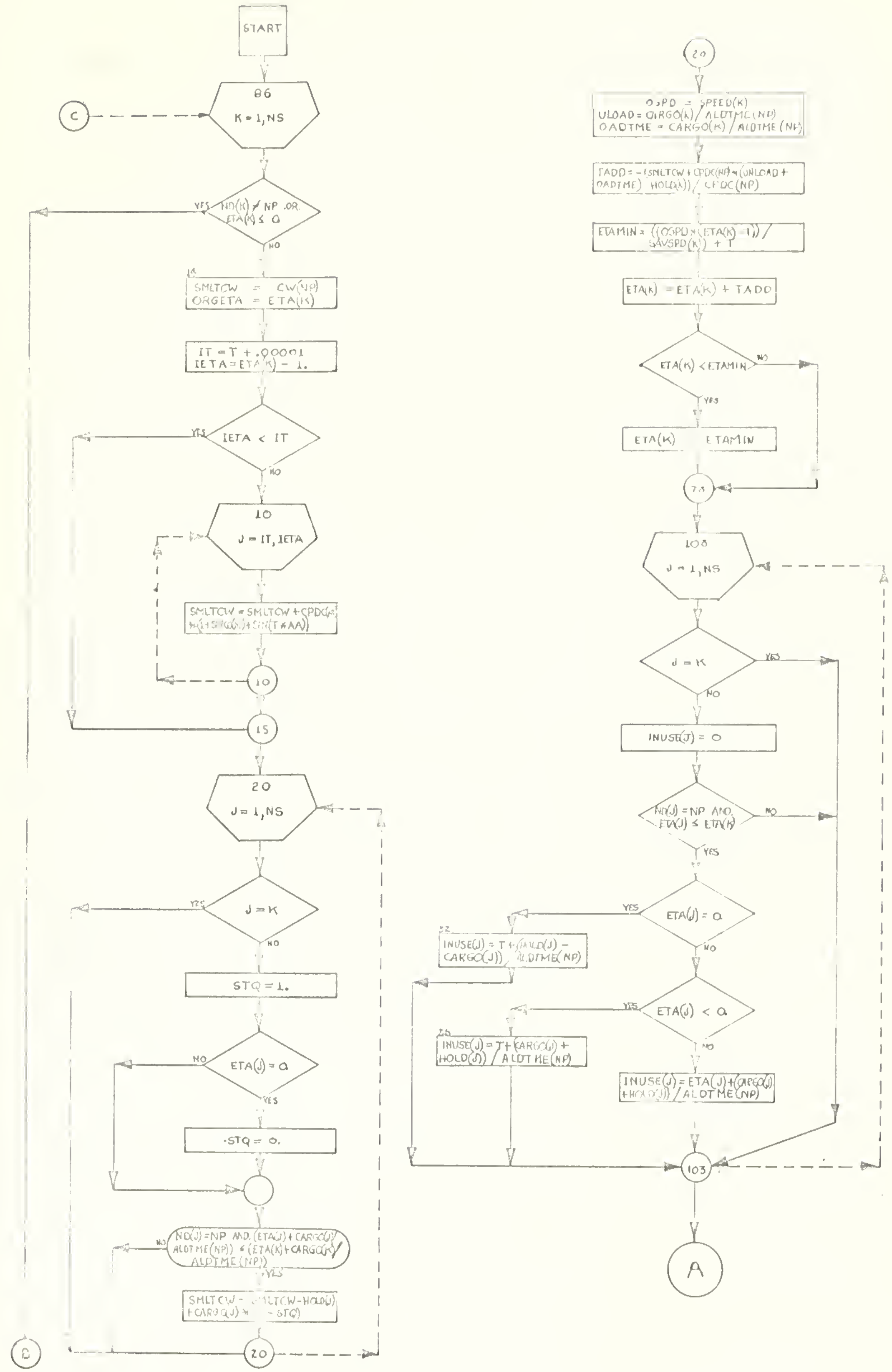
```
$IBFTC DEPART  NODECK
C
C      ------------------------------------------------------------------
C      THIS SUBPROGRAM SAILS A SHIP WHEN ITS TIME-OF-DEPARTURE IS REACHED
C      ------------------------------------------------------------------
C
     0SUBROUTINE  DEPART(NDOCKS, T, DCKTME, IDOCK, NP, HOLD, DIS, SPEED,
     1CPDC, CR1, CR2,      SINCO, AA, CW, DELT, ND, ETA, CPD, NN, PRTME,
     2DCKDLY, TPRTME, SAVTME, CHCK, SAILTM, BGNWRK, SAVETA, SAVSPD)
     0DIMENSION  NDOCKS(5), DCKTME(5,5), IDOCK(10,10), HOLD(10), ND(5),
     1DIS(10,10), SPEED(10), CPDC(5), CR1(5), CR2(5),        SINCO(5),
     2CW(5), ETA(10), CPD(5), PRTME(10), DCKDLY(10), TPRTME(10),
     3SAVTME(10), CHCK(10), SAILTM(10), BGNWRK(5), SAVETA(10),
     4SAVSPD(10)
      COMMON I1,I2
   32 DO 31 J = 1,NN
      IF(T .LE. DCKTME(NP,J) .AND. DCKTME(NP,J) .LT. T + 1.) GO TO 33
      GO TO 31
   33 K = IDOCK(NP,J)
   69 GO TO (36,37),NP
   36 ND(K) = 2
      KK = 2
      GO TO 40
   37 ND(K) = 1
      KK = 1
   40 IDOCK(NP,J) = 0
      SPEED(K) = SAVSPD(K)
      ETA(K) = DCKTME(NP,J) + DIS(NP,KK) / (SPEED(K) * 24.)
      PRTME(K) = DCKTME(NP,J) - SAVETA(K)
      TPRTME(K) = TPRTME(K) + PRTME(K)
      SAVTME(K) = DCKTME(NP,J)
      DCKTME(NP,J) = 0.
      CHCK(K) =  0.
   31 CONTINUE
   45 RETURN
      END
```

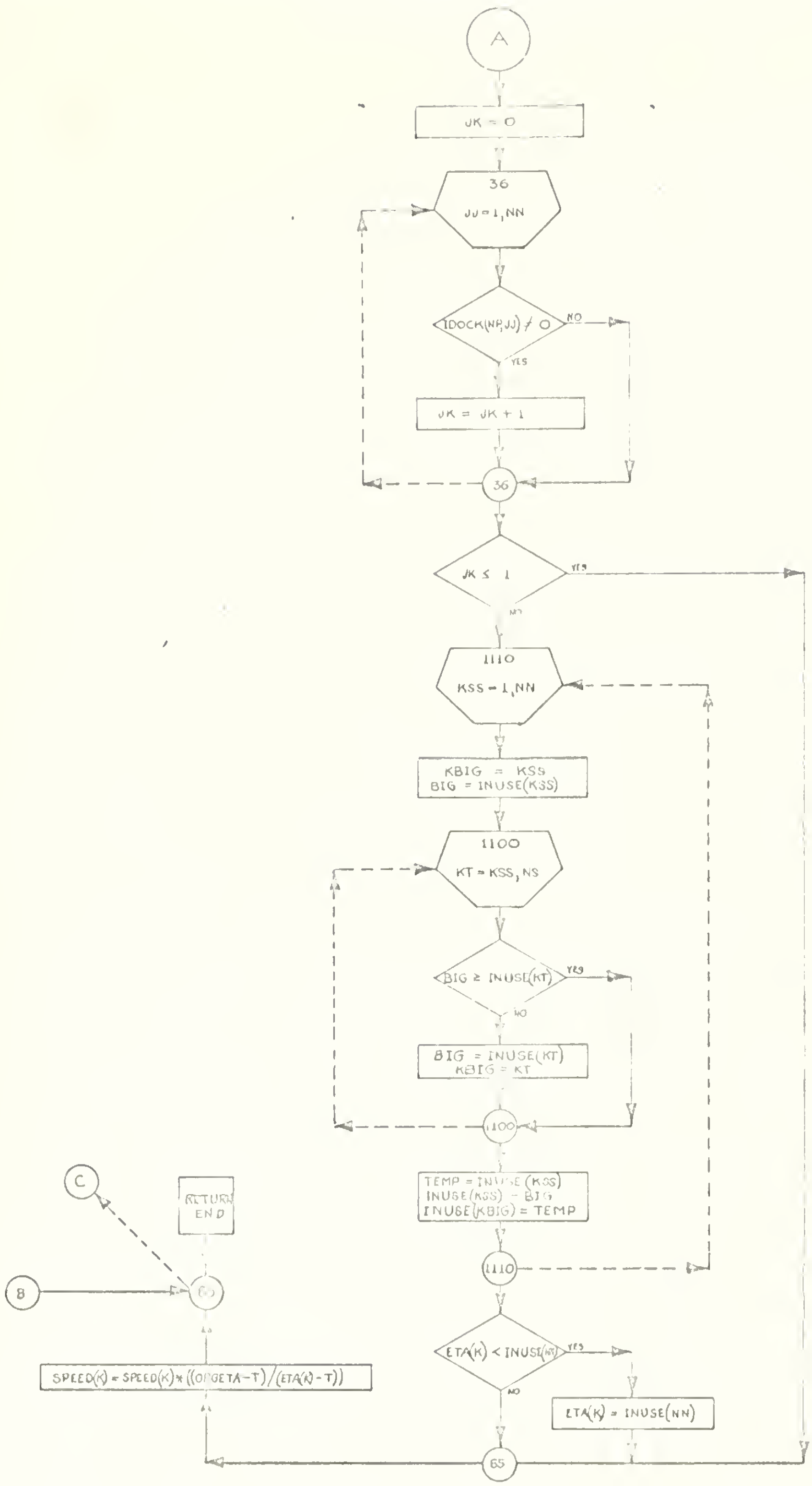
TITLE: SCAN - A subroutine whose purpose is to synchronize a vessel's ETA with an open dock and cargo waiting to be put on board.

DESCRIPTION: SCAN will generate the cargo that will be available for shipment on the day a vessel is scheduled to arrive in port and look for a vacant dock. If SCAN finds that there will be no cargo or that all docks are occupied, it will delay the arrival time to coincide with a build-up of cargo or an open dock. In the same manner SCAN can speed up a ship that is traveling slower than its maximum speed if cargo has built up in port.

VARIABLE	TYPE	S/A	I/O	DESCRIPTION
K	FX	S		Ship counter.
NS	FX	S	I	Number of ships.
ND	FX	A	I	Destination of the Kth ship.
NP	FX	S	I	Number of the port.
ETA	FL	A	I;O	Estimated-time-of-arrival of the Kth ship.
CHCK	FL	A	I	Establishes the time when changing the Kth ship's ETA is Studied.
SMLTCW	FL	S		Simulated cargo awaiting shipment.
CW	FL	A	I	Cargo awaiting shipment at the NPth port.
T	FX	S	I	Master time.
CADC	FL	A	I	Daly cargo arrival rate in the NPth port.
SINCO	FL	A	I	Amplitude of the annual fluctuation.
AA	FL	S	I	Constant equal to 2.*3.1415927/360.
[illegible]	FL	A	I	Cargo capacity of the Jth ship.
TADD	FL	S		Time added to or subtracted from the ETA.
[illegible]	FL	A	I	Unloading and loading rate in the Mth port.
SPEED	FL	A	I;O	Speed of the Kth ship.
[illegible]	FL	S		Original ETA
[illegible]	FL	A		Time to be added to J ship.
[illegible]	FL	A	I	Amount of cargo actually on board.

SCAN


START
86
K = 1, NS
C
ND(K) ≠ NP .OR. ETA(K) ≤ 0
YES
NO
SMLTCW = CW(NP)
ORGETA = ETA(K)
IT = T + .00001
IETA = ETA(K) - 1.
IETA < IT
10
J = IT, IETA
10
15
20
J = 1, NS
J = K
STQ = 1.
ETA(J) = 0
STQ = 0.
SMLTCW = SMLTCW-HOLD(J)
20
B
20
OSPD = SPEED(K)
ULOAD = CARGO(K) / ALOTME(NP)
OADTME = CARGO(K) / ALOTME(NP)
ETAMIN = ((OSPD * (ETA(K) - T)) / SAVSPD(K)) + T
ETA(K) = ETA(K) + TADD
ETA(K) < ETAMIN
ETA(K) ETAMIN
108
J = 1, NS
J = K
INUSE(J) = 0
ND(J) = NP AND. ETA(J) ≤ ETA(K)
ETA(J) = 0
INUSE(J) = T + (HOLD(J) - CARGO(J)) / ALOTME(NP)
ETA(J) < 0
INUSE(J) = T + CARGO(J) + HOLD(J) / ALOTME(NP)
INUSE(J) = ETA(J) + (CARGO(J) + HOLD(J)) / ALOTME(NP)
103
A


A
JK = 0
36
JJ = 1, NN
IDOCK(NP,JJ) ≠ 0
NO
YES
JK = JK + 1
36
JK ≤ 1
YES
NO
1110
KSS = 1, NN
KBIG = KSS
BIG = INUSE(KSS)
1100
KT = KSS, NS
BIG ≥ INUSE(KT)
YES
NO
BIG = INUSE(KT)
KBIG = KT
1100
TEMP = INUSE(KSS)
INUSE(KSS) = BIG
INUSE(KBIG) = TEMP
1110
ETA(K) < INUSE(NN)
YES
NO
ETA(K) = INUSE(NN)
65
SPEED(K) = SPEED(K) * ((ORGETA-T)/(ETA(K)-T))
C
RETURN
END
B

```
$IBFTC SCAN    NODECK
C
C     ------------------------------------------------------------------
C     THIS PROGRAM ALTERS A SHIP,S SPEED TO SYNCHRONIZE ITS ETA WITH AN
C     OPEN DOCK AND CARGO WAITING TO BE PUT ON BOARD
C     ------------------------------------------------------------------
C
     0SUBROUTINE SCAN(NS, ND, NP, ETA, HOLD, CHCK, CPDC, CW, SINCO, T,
     1AA, CARGO, ALDTME, NN, SPEED, SAVSPD, IDOCK)
     0DIMENSION ND(10), ETA(10), HOLD(10), CHCK(10), CPDC(5), CW(5),
     1SINCO(5), USE(10), CARGO(10), ALDTME(5), SPEED(10),
     2SAVSPD(10), IDOCK(10,10)
      DO 86 K = 1,NS
      IF(ND(K) .NE. NP .OR. ETA(K) .LE. 0.) GO TO 86
      ORGETA = ETA(K)
   14 SMLTCW = CW(NP)
      IT = T + .00001
      IETA = ETA(K) - 1.
      IF(IETA .LT. IT) GO TO 15
      DO 10 J = IT,IETA
      SMLTCW = SMLTCW + CPDC(NP) * (1. + SINCO(NP) * SIN(T * AA))
   10 CONTINUE
   15 DO 20 J = 1,NS
      IF( J .EQ. K ) GO TO 20
      STQ = 1.
      IF(ETA(J) .EQ. 0.) STQ = 0.
     0IF(ND(J).EQ.NP.AND.(ETA(J)+CARGO(J)/ALDTME(NP)) .LE. (ETA(K)+
     1CARGO(K)/ALDTME(NP))) SMLTCW = SMLTCW-HOLD(J)+CARGO(J)*(1.-STQ)
   20 CONTINUE
      OSPD = SPEED(K)
      UNLOAD = CARGO(K) / ALDTME(NP)
      OADTME = HOLD(K) / ALDTME(NP)
      TADD =-(SMLTCW+CPDC(NP)*(UNLOAD+OADTME)-HOLD(K)) / CPDC(NP)
      ETAMIN = ((OSPD*(ETA(K) - T))/SAVSPD(K)) + T
      ETA(K) = ETA(K) + TADD
      IF(ETA(K) .LT. ETAMIN) ETA(K) = ETAMIN
   73 DO 103 J = 1,NS
      IF(J .EQ. K) GO TO 103
```

```
      USE(J) = 0.
      IF(ND(J) .EQ. NP .AND. ETA(J) .LE. ETA(K)) GO TO 67
      GO TO 103
   67 IF(ETA(J) .EQ. 0.) GO TO 52
      IF(ETA(J) .LT. 0.) GO TO 56
      USE(J) = ETA(J) + (CARGO(J) + HOLD(J)) / ALDTME(NP)
      GO TO 103
   52 USE(J) = T + (HOLD(J) - CARGO(J)) / ALDTME(NP)
      GO TO 103
   56 USE(J) = T + (CARGO(J) + HOLD(J)) / ALDTME(NP)
  103 CONTINUE
      JK = 0
      DO 36 JJ = 1,NN
      IF(IDOCK(NP,JJ) .NE. 0) JK = JK + 1
   36 CONTINUE
      IF(JK .LE. 1) GO TO 85
      DO 1110 KSS = 1,NN
      KBIG = KSS
      BIG = USE(KSS)
      DO 1100 KT = KSS,NS
      IF(BIG .GE. USE(KT)) GO TO 1100
      BIG = USE(KT)
      KBIG = KT
 1100 CONTINUE
      TEMP = USE(KSS)
      USE(KSS) = BIG
      USE(KBIG) = TEMP
 1110 CONTINUE
      IF(ETA(K) .LT. USE(NN)) ETA(K) = USE(NN)
   85 SPEED(K) = SPEED(K)* ((ORGETA     - T)/(ETA(K) - T))
   86 CONTINUE
      RETURN
      END
```

TITLE: FUEL

DESCRIPTION: Fuel computes the amount of fuel a vessel consumes depending upon the speed the vessel is traveling at the beginning of the day.

LANGUAGE: FORTRAN IV

VARIABLE	TYPE	S/A	I/O	DESCRIPTION
KD	FX	A	I	The destination of the Kth ship.
ETA	FL	A	I	Estimated-time-of-arrival of the Kth ship.
T	FL	S	I	Master time.
TONS	FL	A	O	The tons of fuel consumed by the Kth ship.
TOTONS	FL	A	O	The total amount of fuel consumed by the Kth ship since the beginning of the simulation run.

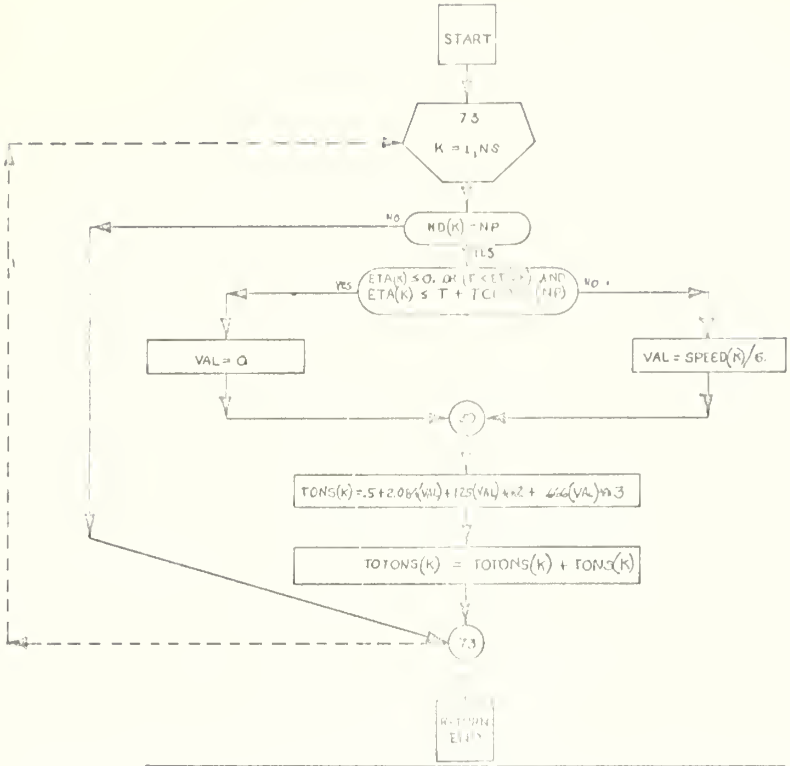
TITLE: COST

DESCRIPTION: COST computes the total cost of operating each ship.

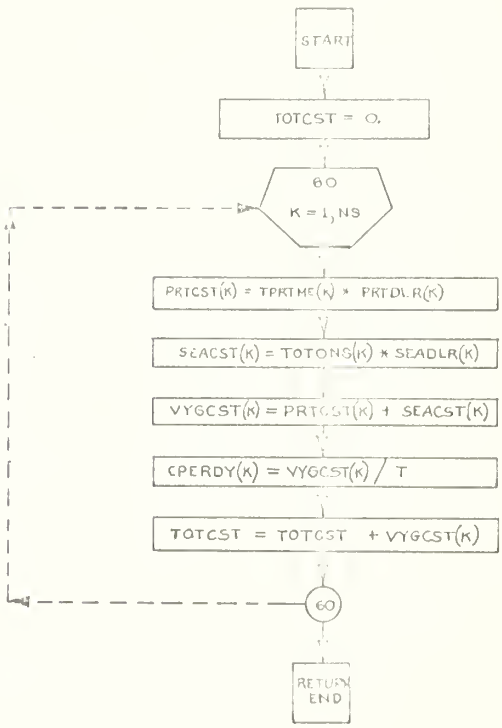
LANGUAGE: FORTRAN IV (IBM 7040)

VARIABLE	TYPE	S/A	I/O	DESCRIPTION
PRTCST	FL	A	O	The cost of the total time in port of the Kth ship.
PRTIME	FL	A	I	The total time (day) the Kth ship was in port.
PRTDLR	FL	A	I	Cost per day of a ship in port.
SEACST	FL	A	O	The cost of the Kth ship at sea.
TOTONS	FL	A	I	The amount of fuel the Kth ship has used.
SEADLR	FL	A	I	The cost per ton of fuel used.
VYCOST	FL	A	O	Total voyage cost of the Kth ship.
[illegible]	FL	A	O	Daily operating cost.
TOTCST	FL	A	O	Total cost of all ships.

FUEL


START
73
K = 1, NS
NO
ND(K) - NP
YES
YES
NO
VAL = 0
VAL = SPEED(K)/6.
TONS(K) = .5 + 2.08(VAL) + 125(VAL)**2 + 616(VAL)**3
TOTONS(K) = TOTONS(K) + TONS(K)
73

COST


START
TOTCST = 0.
60
K = 1, NS
PRTCST(K) = TPRTME(K) * PRTDLR(K)
SEACST(K) = TOTONS(K) * SEADLR(K)
VYGCST(K) = PRTCST(K) + SEACST(K)
CPERDY(K) = VYGCST(K) / T
TOTCST = TOTCST + VYGCST(K)
60
RETURN
END

```
$IBFTC FUEL     NODECK
C
C      ------------------ ----------------------------------------------------
C      THIS PROGRAM COMPUTES THE AMOUNT OF FUEL A VESSEL CONSUMES.
C      ------------------ ----------------------------------------------------
C
      SUBROUTINE FUEL(ND, NS, NP, T, ETA, TCLOSE, SPEED, TONS, TOTONS)
      DIMENSION ND(10), ETA(10), TCLOSE(5), TONS(10), TOTONS(10), SPEED(
     110)
      DO 73 K = 1,NS
      IF(ND(K) .EQ. NP) GO TO 15
      GO TO 73
   15 IF(ETA(K) .LE. 0. .OR. (T .LT. ETA(K) .AND. ETA(K) .LE. T+TCLOSE(N
     1P))) GO TO 26
      VAL = SPEED(K) / 6.
   30 TONS(K) = .5 + 2.08 * VAL + 1.25 * VAL**2 + .666 * VAL**3
      TOTONS(K) = TOTONS(K) + TONS(K)
      GO TO 73
   26 VAL = 0.
      GO TO 30
   73 CONTINUE
      RETURN
      END
```

```
$IBFTC COST     NODECK
C
C     ------------------------------------------------------------------
C     THIS PROGRAM COMPUTES THE TOTAL COST OF OPERATING EACH SHIP.
C     ------------------------------------------------------------------
C
     0SUBROUTINE COST(NS, T, TOTCST, PRTCST, TPRTME, PRTDLR, SEACST, SEA
     1TME, SEADLR, VYGCST, CPERDY, TDKDLY, TOTONS)
     0DIMENSION  PRTCST(10), TPRTME(10), PRTDLR(10), SEACST(10), SEATME(
     110), SEADLR(10), VYGCST(10), CPERDY(10), TDKDLY(10), TOTONS(10)
      TOTCST = 0.
      DO 60 K = 1,NS
      PRTCST(K) = TPRTME(K) * PRTDLR(K)
      SEACST(K) = TOTONS(K) * SEADLR(K)
      VYGCST(K) = PRTCST(K) + SEACST(K)
      CPERDY(K) = VYGCST(K) / T
      TOTCST = TOTCST + VYGCST(K)
   60 CONTINUE
      RETURN
      END
```

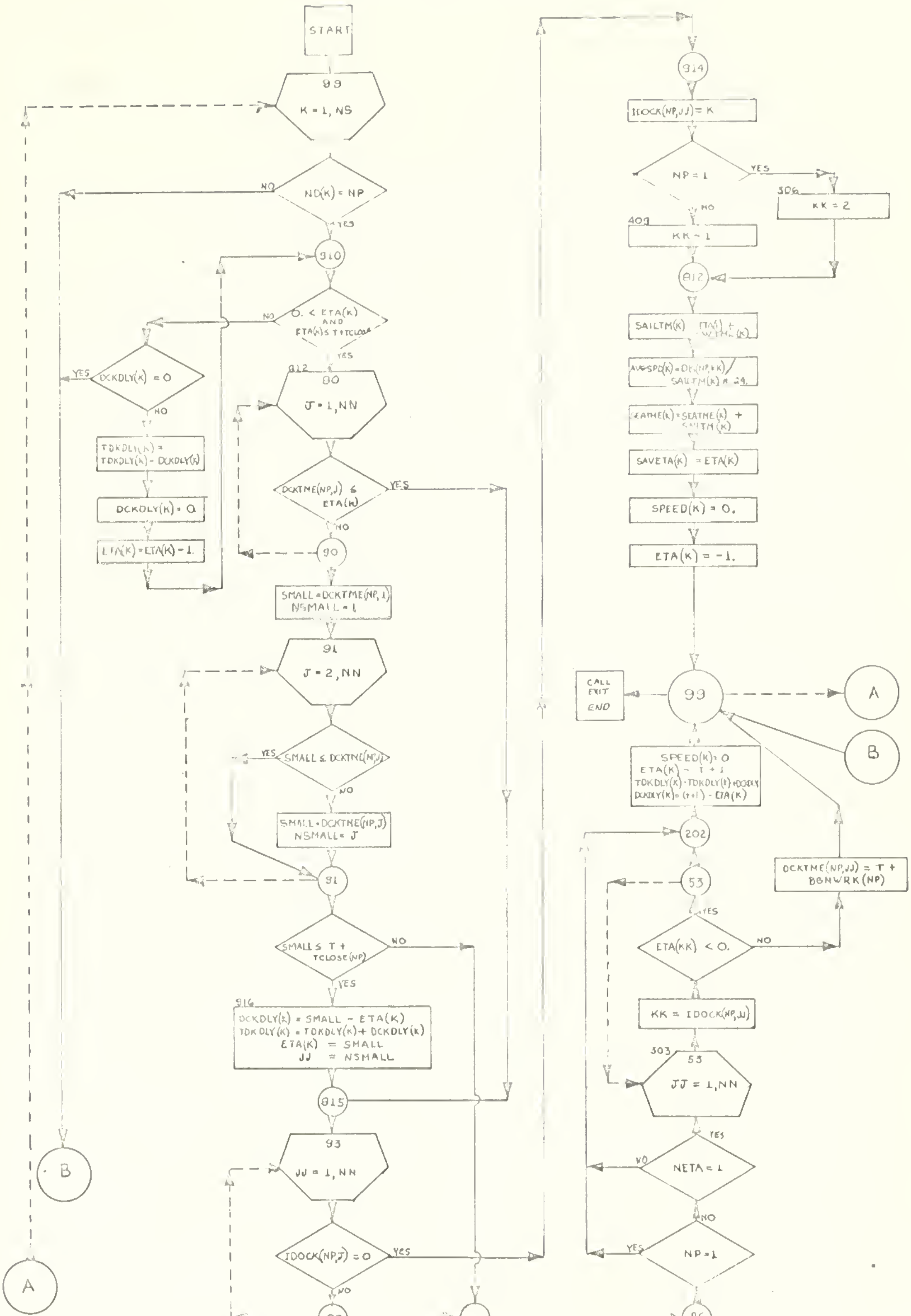
TITLE: ARRIVE

DESCRIPTION: ARRIVE docks vessels when their ETA is reached.

LANGUAGE: FORTRAN IV

VARIABLE	TYPE	S/A	I/O	DESCRIPTION
NS	FX	S	I	The number o ships in use by the model.
ND	FX	A	I	The destination of the Kth ship.
NP	FX	S	I	The number of the port.
T	FL	S	I	Master time.
TCLOSE	FL	A	I	The closing time of the NPth port.
DCKDLY	FL	A	I;O	Dock delay caused by a vessel waiting for a vacant port.
[illegible]	FX	S	I	The number of docks in port.
ETA	FL	A	I	Estimated-time-of-arrival of the Kth ship.
DCKTME	FL	A	I	The time the (NP,J) dock will open up--this is actually a time-of-departure.
NETA	FX	S	I	A tag number telling the program to sail ships from port two to permit an inbound ship to land.
SPEED	FL	A	I	Speed of the Kth ship.
IDOCK	F	A	I	A particular dock that a ship is in.

ARRIVE


START
99
K = 1, NS
ND(K) = NP
NO
YES
910
0. < ETA(K) AND ETA(K) ≤ T + TCLOSE
DCKDLY(K) = 0
TDKDLY(K) = TDKDLY(K) - DCKDLY(K)
DCKDLY(K) = 0
ETA(K) = ETA(K) - 1.
912
80
J = 1, NN
DCKTME(NP,J) ≤ ETA(K)
90
SMALL = DCKTME(NP,1)
NSMALL = 1
91
J = 2, NN
SMALL ≤ DCKTME(NP,J)
SMALL = DCKTME(NP,J)
NSMALL = J
91
SMALL ≤ T + TCLOSE(NP)
916
DCKDLY(K) = SMALL - ETA(K)
TDKDLY(K) = TDKDLY(K) + DCKDLY(K)
ETA(K) = SMALL
JJ = NSMALL
815
93
JJ = 1, NN
IDOCK(NP,J) = 0
93
B
A
914
IDOCK(NP,JJ) = K
NP = 1
306
KK = 2
409
KK = 1
812
SAILTM(K)
SEATME(K) = SEATME(K) + SAILTM(K)
SAVETA(K) = ETA(K)
SPEED(K) = 0.
ETA(K) = -1.
CALL
EXIT
END
99
A
B
SPEED(K) = 0
ETA(K) = T + 1
202
53
ETA(KK) < 0.
DCKTME(NP,JJ) = T + BGNWRK(NP)
KK = IDOCK(NP,JJ)
303
53
JJ = 1, NN
NETA = 1
NP = 1
86

```
$IBFTC ARRIVE  NODECK
C
C     ------------------------------------------------------------------
C     THIS PROGRAM DOCKS VESSELS WHEN THEIR ETA IS REACHED.
C     ------------------------------------------------------------------
C
     0SUBROUTINE  ARRIVE(NDOCKS, NS, NP, T, TCLOSE, UNLDT, ALDTME, ETA,
     1ENDWRK, OVTIME, WRKDAY, BGNWRK, IDOCK, DCKTME, ND, NN, PRTME,
     2DCKDLY, TPRTME, SAVTME, SAILTM, SEATME, TDKDLY, SAVETA, DIS, AVGSP
     3D, SAVSPD, SPEED, NETA)
     0DIMENSION  NDOCKS(5), TCLOSE(5),   UNLDT(10), ETA(10), ENDWRK(5),
     1OVTIME(5), WRKDAY(5), BGNWRK(5), IDOCK(10,10), DCKTME(5,5), ND(5),
     2ALDTME(5), PRTME(10), DCKDLY(10), TPRTME(10), SAVTME(10), SAILTM(1
     30), SEATME(10), TDKDLY(10), SAVETA(10), DIS(10,10), AVGSPD(10), SA
     4VSPD(10), SPEED(10)
      DO 99 K = 1,NS
      IF(ND(K) .EQ. NP) GO TO 910
      GO TO 99
  910 IF(0. .LT. ETA(K) .AND. ETA(K) .LE. T + TCLOSE(NP)) GO TO 912
      IF(DCKDLY(K) .EQ. 0.) GO TO 99
      TDKDLY(K) = TDKDLY(K) - DCKDLY(K)
      DCKDLY(K) = 0.
      ETA(K) = ETA(K) - 1.
      GO TO 910
  912 DO 90 J = 1,NN
      IF(DCKTME(NP,J) .LE. ETA(K)) GO TO 915
   90 CONTINUE
      SMALL = DCKTME(NP,1)
      NSMALL = 1
      DO 91 J = 2,NN
      IF(SMALL .LE. DCKTME(NP,J)) GO TO 91
      SMALL = DCKTME(NP,J)
      NSMALL = J
   91 CONTINUE
      IF(SMALL .LE. T + TCLOSE(NP)) GO TO 916
   86 GO TO  (202,206), NP
  206 GO TO (303,202), NETA
  303 DO 53 JJ = 1,NN
```

```
      KK = IDOCK(NP,JJ)
      IF(ETA(KK) .LT. 0.) GO TO 53
      DCKTME(NP,JJ) = T + BGNWRK(NP)
      GO TO 99
   53 CONTINUE
  202 DCKDLY(K) = (T + 1.) - ETA(K)
      TDKDLY(K) = TDKDLY(K) + DCKDLY(K)
      ETA(K) = T + 1.
      SPEED(K) = 0.
      GO TO 99
  916 DCKDLY(K) = SMALL - ETA(K)
      TDKDLY(K) = TDKDLY(K) + DCKDLY(K)
      ETA(K) = SMALL
      JJ= NSMALL
  915 DO 93 JJ = 1,NN
      IF(IDOCK(NP,JJ) .EQ. 0) GO TO 914
   93 CONTINUE
      GO TO 86
  914 IDOCK(NP,JJ)= K
      GO TO (306,409), NP
  306 KK = 2
      GO TO 812
  409 KK = 1
  812 SAILTM(K) = ETA(K) - SAVTME(K)
      AVGSPD(K) = DIS(NP,KK) / (SAILTM(K) * 24. )
      SEATME(K) = SEATME(K) + SAILTM(K)
      SAVETA(K) = ETA(K)
      SPEED(K) = 0.
      ETA(K) = -1.
   99 CONTINUE
      GO TO 100
  100 RETURN
      END
```

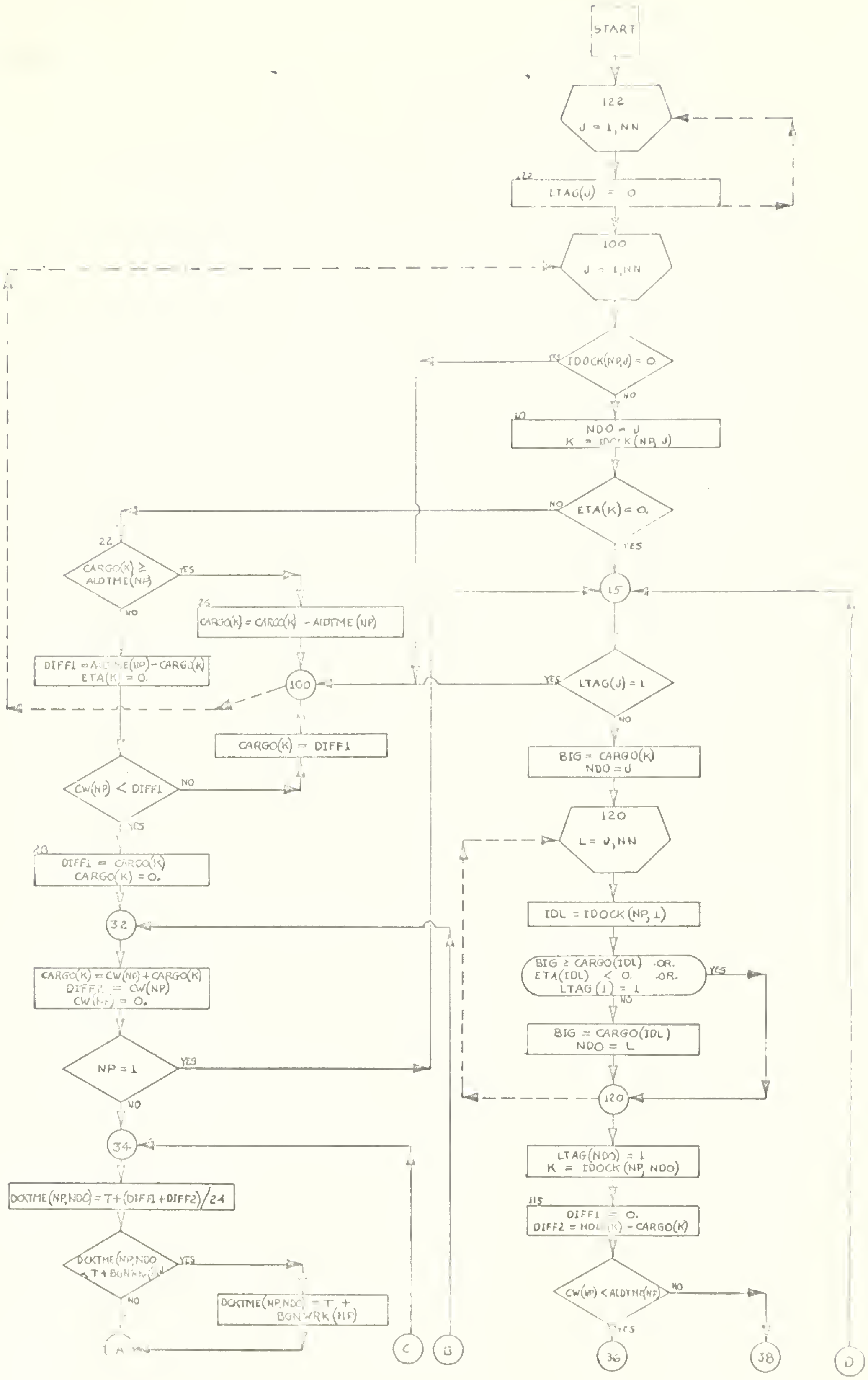
PROGRAM: [illegible]

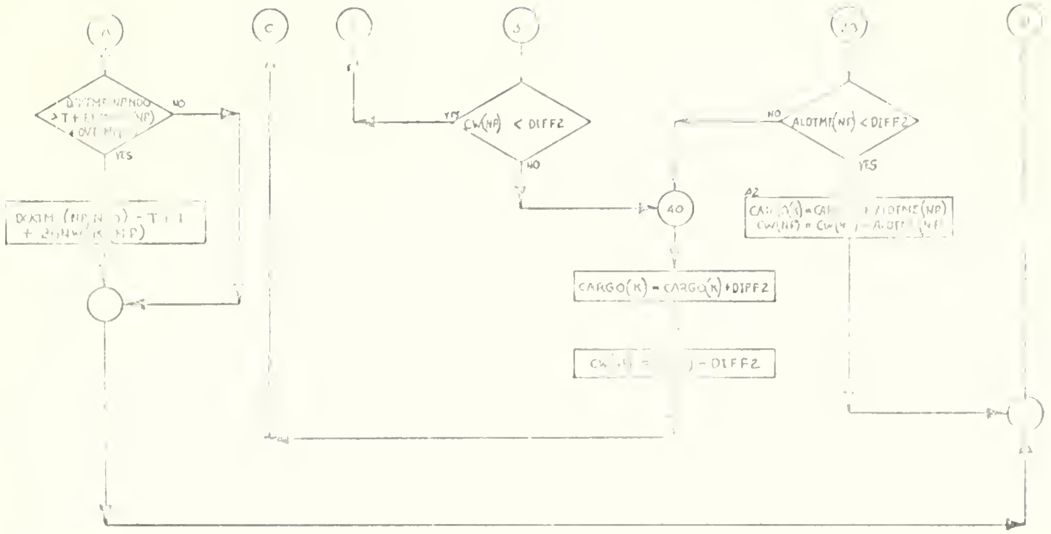
DESCRIPTION: This program loads and discharges cargo from a ship; then it computes the time-of-departure for the ship.

LANGUAGE: FORTRAN IV

VARIABLE	TYPE	S/A	I/O	DESCRIPTION
IDOCK	FX	A	I	Designates a particular ship in dock.
CARGO	FL	A	I	Amount of cargo on board the [illegible] ship.
[illegible]DTME	FL	A	I	Loading and unloading rates.
CW	FL	A	I	Amount of cargo awaiting shipment at the NPth port.
DCKTME	FL	A	O	Time a particular dock will be open.
BGNWRK	FL	A	I	Begin work at the NPth port.
ENDWRK	FL	A	I	End work at the NPth port
OVTIME	FL	A	I	Overtime at the NPth port.

LOAD


START
122
J = 1, NN
LTAG(J) = 0
100
J = 1, NN
IDOCK(NP,J) = 0.
YES
NO
NDO = J
K = IDOCK(NP, J)
ETA(K) = 0.
NO
YES
15
22
CARGO(K) ≥ ALDTME(NP)
YES
NO
CARGO(K) = CARGO(K) - ALDTME(NP)
DIFF1 = ALDTME(NP) - CARGO(K)
ETA(K) = 0.
100
LTAG(J) = 1
YES
NO
CARGO(K) = DIFF1
BIG = CARGO(K)
NDO = J
CW(NP) < DIFF1
NO
YES
120
L = J, NN
DIFF1 = CARGO(K)
CARGO(K) = 0.
32
IDL = IDOCK(NP, L)
CARGO(K) = CW(NP) + CARGO(K)
DIFF2 = CW(NP)
CW(NP) = 0.
BIG ≥ CARGO(IDL) .OR.
ETA(IDL) < 0. .OR.
LTAG(L) = 1
YES
NO
BIG = CARGO(IDL)
NDO = L
NP = 1
YES
NO
120
34
LTAG(NDO) = 1
K = IDOCK(NP, NDO)
DCKTME(NP,NDO) = T + (DIFF1 + DIFF2)/24
115
DIFF1 = 0.
DIFF2 = HOLD(K) - CARGO(K)
DCKTME(NP,NDO) ≥ T + BGNWRK(NP)
YES
NO
DCKTME(NP,NDO) = T + BGNWRK(NP)
CW(NP) < ALDTME(NP)
NO
YES
A
C
B
36
38
D


C
NO
YES
YES
CW(NP) < DIFFZ
NO
NO
ALOTMT(NP) < DIFFZ
YES
40
CARGO(K) = CARGO(K) + DIFFZ
DIFFZ

```
$IBFTC LOAD    NODECK
C
C     ------------------ ---------------------------------------------
C     THIS PROGRAM LOADS AND DISCHARGES CARGO FROM A SHIP THEN IT
C     COMPUTES THE TIME-OF-DEOARTURE FOR THE SHIP.
C     ------------------ ---------------------------------------------------------
C
     0SUBROUTINE LOAD(NN, IDOCK, ETA, CARGO, ALDTME, CW, NP, DCKTME,
     1BGNWRK, ENDWRK, OVTIME, HOLD, T)
     0DIMENSION IDOCK(10,10), ETA(10), CARGO(10), ALDTME(5),  CW(5),
     1DCKTME(5,5),   BGNWRK(5), ENDWRK(5), OVTIME(5), HOLD(10),
     2LTAG(10)
      DO 122 J = 1,NN
  122 LTAG(J) = 0
      DO 100 J = 1,NN
      IF(IDOCK(NP,J) .LE. 0) GO TO 100
      NDO = J
   10 K = IDOCK(NP,J)
      IF(ETA(K) .EQ. 0.) GO TO 15
   22 IF(CARGO(K) .GE. ALDTME(NP))GO TO 26
      DIFF1 = ALDTME(NP)- CARGO(K)
      ETA(K) = 0.
      IF(CW(NP) .LT. DIFF1) GO TO 28
      CARGO(K) = DIFF1
      CW(NP) = CW(NP) - DIFF1
      GO TO 100
   26 CARGO(K) = CARGO(K) - ALDTME(NP)
      GO TO 100
   28 DIFF1 = CARGO(K)
      CARGO(K) = 0.
   32 CARGO(K) = CW(NP) + CARGO(K)
      DIFF2 = CW(NP)
      CW(NP) = 0.
      GO TO (15,34), NP
   34 DCKTME(NP,NDO) = T + (DIFF1 + DIFF2) / 24.
      IF(DCKTME(NP,NDO).LT.T+BGNWRK(NP))DCKTME(NP,NDO)=T+BGNWRK(NP)
      IF(DCKTME(NP,NDO).GT.T+ENDWRK(NP)+OVTIME(NP))DCKTME(NP,NDO)=T
     1 + 1. + BGNWRK(NP)
```

```
 15 IF(LTAG(J) .EQ. 1) GO TO 100
    BIG = CARGO(K)
    NDO = J
    DO 120 L = J,NN
    IDL = IDOCK(NP,L)
    IF(IDL .EQ. 0) GO TO 120
    IF(BIG .GE. CARGO(IDL) .OR. ETA(IDL) .LT. 0. .OR. LTAG
   1(L) .EQ. 1) GO TO 120
    BIG = CARGO(IDL)
    NDO = L
120 CONTINUE
    LTAG(NDO) = 1
    K = IDOCK(NP, NDO)
115 DIFF1 = 0.
    DIFF2 = HOLD(K) - CARGO(K)
    IF(CW(NP) .LT. ALDTME(NP))GO TO 36
    IF(ALDTME(NP).LT. DIFF2)  GO TO 42
 40 CARGO(K) = CARGO(K) + DIFF2
    CW(NP) = CW(NP) - DIFF2
    GO TO 34
 42 CARGO(K) = CARGO(K) + ALDTME(NP)
    CW(NP) = CW(NP) - ALDTME(NP)
    GO TO 15
 36 IF(CW(NP) .LT. DIFF2) GO TO 32
    GO TO 40
100 CONTINUE
    RETURN
    END
```

```
INPUT DATA FOR CASE NUMBER....16

NS = 4   NOP = 2   T = 0.   DELT = 1.0   TFIN = 1000.0   LSCAN  2   NPRT  2   NETA = 1
CPDC( 1) = 1.50      CW( 1) = 0.        SINCOT( 1) = 0.
CPDC( 2) = 0.50      CW( 2) = 0.        SINCOT( 2) = 0.
CR1( 1) =  1.0      CR2( 1) = 0.   CR1( 2)   1.0      CR2( 2) = -0.
    DIS(1,1) =      0.        DIS(1,2) =  2500.0        DIS(2,1)  = 2500.0        DIS(2,2) =      0.

ALDTME(1) =        3.60  ALDTME(2) =        1.60
NDOCKS( 1) = 2        TCLOSE( 1) = 0.90  NDOCKS( 2) = 2        TCLOSE( 2) = 0.90
BGNWRK( 1) = 0.35      ENDWRK( 1) = 0.70  BGNWRK( 2)   0.35      ENDWRK( 2) = 0.70
WRKDAY( 1) = 0.35      OVTIME( 1) = 0.17  WRKDAY( 2)   0.35      OVTIME( 2) = 0.19
   DCKTME(1,1) = 0.        DCKTME(1,2) = 0.        DCKTME(2,1) = 0.        DCKTME(2,2) = 0.
    IDOCK(1,1) = 1        IDOCK(1,2) = 0        IDOCK(2,1) = 0        IDOCK(2,2) = 0
 TPRTME(1) = 0.      TDKDLY(1) = 0.      SAVTME(1) = 0.      SAILTM(1) = 0.      SEATME(1) = 0.      CHCKT(1) = 0.
 TPRTME(2) = 0.      TDKDLY(2) = 0.      SAVTME(2) = 0.      SAILTM(2) = 0.      SEATME(2) = 0.      CHCKT(2) = 0.
 TPRTME(3) = 0.      TDKDLY(3) = 0.      SAVTME(3) = 0.      SAILTM(3) = 0.      SEATME(3) = 0.      CHCKT(3) = 0.
 TPRTME(4) = 0.      TDKDLY(4) = 0.      SAVTME(4) = 0.      SAILTM(4) = 0.      SEATME(4) = 0.      CHCKT(4) = 0.

 SHIP  SPEED    HOLD      ETA      ND              PRTDLR    SEADLR    CARGO
(1),    12.0    12.0     0.         1              1700.00    22.40     0.
(2),    12.0    12.0     6.5        1              1700.00    22.40    12.00
(3),    12.0    12.0     2.2        2              1700.00    22.40    12.00
(4),    12.0    12.0     7.1        2              1700.00    22.40    12.00

                          CASE SOLUTION

  SHIP      TDKDLY     SEATME    SEACST     TPRTME     PRTCST     VYGCST     CPERDY
 (1),         0.        564.24 191046.29    434.79 739150.92 930197.20     929.27

 (2),         0.        562.06 191046.29    436.29 741700.93 932747.21     931.82

 (3),         0.        566.44 191035.09    430.59 732010.93 923046.02     922.12

 (4),         0.        562.66 192008.67    432.69 735580.92 927589.59     926.66

        THE TOTAL COST FOR THIS SOLUTION IS 3713580.00  DOLLARS
CHTOTL(1) =   1867.70       CHMAX(1) =        8.30
CHTOTL(2) =   2021.80       CHMAX(2) =        5.50

        WAREHOUSE COST FOR PORT(1) IS       0.
        WAREHOUSE COST FOR PORT(2) IS       0.
```

SAMPLE OUTPUT UPON COMPLETION OF A COMPUTER RUN

```
TIME  CH(1)  DOCK TIME     SHIP     CH(2)  DOCK TIME     SHIP
 9.0   1.50                          1.50
             (1,1) =  0.     2              (2,1) =  0.     4
             (1,2) =  0.     0              (2,2) =  0.     0
                                                              SHIP  ND        ETA       CARGO       PRTME      SAILTM      SPEED
                                                              (1),   2       17.03      12.00       0.          0.         12.00
                                                              (2),   1       -1.00       8.40       0.          9.83        0.
                                                              (3),   1       17.70       5.40       0.          0.          7.55
                                                              (4),   2       -1.00       1.20       0.          0.          0.

TIME  CH(1)  DOCK TIME     SHIP     CH(2)  DOCK TIME     SHIP
10.0   3.00                          0.
             (1,1) =  0.     2              (2,1) =  0.     0
             (1,2) =  0.     0              (2,2) =  0.     0
                                                              SHIP  ND        ETA       CARGO       PRTME      SAILTM      SPEED
                                                              (1),   2       17.03      12.00       0.          0.         12.00
                                                              (2),   1       -1.00       4.80       0.          0.          0.
                                                              (3),   1       19.86       5.40       0.          0.          7.43
                                                              (4),   1       19.03       2.00       3.25        0.         12.00

TIME  CH(1)  DOCK TIME     SHIP     CH(2)  DOCK TIME     SHIP
11.0   4.50                          0.50
             (1,1) =  0.     2              (2,1) =  0.     0
             (1,2) =  0.     1              (2,2) =  0.     0
                                                              SHIP  ND        ETA       CARGO       PRTME      SAILTM      SPEED
                                                              (1),   2       17.03      12.00       0.          0.         12.00
                                                              (2),   1        1.00       1.20       0.          0.          0.
                                                              (3),   1       28.03       5.40       0.          0.          3.86
                                                              (4),   1       20.14       2.00       0.          0.         10.54
```

[illegible] OUTPUT